EARTH TECH | AECOM

Earth Tech AECOM
300 Oceangate, Suite 700, Long Beach, California 90802
T 562.951.2000 F 562.951.2100 www.earthtech.aecom.com

April 21, 2009

Ms. Carolyn d'Almeida
Environmental Protection Agency, Region 9
Superfund Division
75 Hawthorne Street, SFD-7-1
San Francisco, California 94105

Re: Draft DNAPL Feasibility Study
Montrose Superfund Site
20201 S. Normandie Avenue, Los Angeles, California

Dear Ms. d'Almeida:

On behalf of Montrose Chemical Corporation, Earth Tech AECOM submits two copies of the *Draft Dense Non-Aqueous Phase Liquid (DNAPL) Feasibility Study (FS)* for the Montrose Superfund Site located in Los Angeles, California. A DNAPL composed of monochlorobenzene (MCB) and dichlorodiphenyltrichloroethane (DDT) has been detected in certain areas beneath the Site. This FS identifies and evaluates alternatives for the remediation of DNAPL at the Site and has been prepared in accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies under Comprehensive Environmental Response, Compensation, and Liability Act, Interim Final* (U.S. Environmental Protection Agency [EPA], 1988).

Montrose submitted a prior version of the DNAPL FS to EPA in September 1999 (Hargis + Associates, Inc., 1999). EPA subsequently requested that additional testing be conducted to further characterize the nature and extent of DNAPL at the Site and to evaluate candidate technologies through laboratory and field pilot studies. Montrose conducted additional DNAPL-related testing at the Site during the period 2003 through 2008, and sufficient data now exist for re-evaluation of the DNAPL remedial alternatives. This draft DNAPL FS supersedes the prior 1999 version and serves to evaluate candidate technologies and alternatives for the remediation of DNAPL at the Site. If you have any questions regarding this draft FS or require additional copies, please do not hesitate to contact me at (562) 951-2212 or Mr. Mike Palmer at (619) 546-8377.

Sincerely,

EARTH TECH AECOM

Brian Dean
Program Director

cc: Ms. Roberta Blank - EPA (1 copy)
Mr. Jeff Dhont - EPA (1 copy)
Dr. Eva Davis – EPA (1 copy)
Mr. Safouh Sayed - DTSC (1 copy)
Mr. John Dolegowski - CH2M Hill (2 copies)
Mr. Joe Kelly - Montrose Chemical Corp. (1 copy)
Mr. Karl Lytz - Latham & Watkins (1 copy)
Mr. Kelly Richardson - Latham & Watkins (2 copies)
Mr. Paul Sundberg (1 copy)
Mr. Mike Palmer - de maximis (1 copy)
Mr. Mark Schultheis – Geosyntec (1 copy)
Ms. Danielle Ondic – Hargis + Associates (1 copy)
Mr. Dacre Bush – TN & Associates (1 copy)
Dr. Paul Johnson – Arizona State University (1 copy)
Dr. Bernie Kueper – Queen's University (1 copy)
Dr. Brent Sleep – University of Toronto (1 copy)
Mr. John Dudley – URS Corporation (1 copy)

DRAFT
DNAPL FEASIBILITY STUDY
MONTROSE SUPERFUND SITE
20201 S. NORMANDIE AVENUE
LOS ANGELES, CALIFORNIA

April 21, 2009

Prepared For: **Montrose Chemical Corporation of California**
600 Ericksen Avenue NE, Suite 380
Bainbridge Island, Washington 98111

Prepared By: **Earth Tech AECOM**
300 Oceangate, Suite 700
Long Beach, California 90802

EARTH TECH | AECOM

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

Abbreviation	Term
AQMD	Air Quality Management District
ARARs	Applicable or relevant and appropriate requirements
atm	Atmosphere
bgs	Below grade surface
BFS	Bellflower Sand
BHC	Benzene hexachloride
BTUs	British thermal unit
°C	Degrees celsius
CAA	Clean Air Act
CDWR	California Department of Water Resources
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CF	Chloroform
CFR	Code of Federal Regulations
cm/s	Centimeters per second
COCs	Contaminants of concern
cP	Centipoise
CPA	Central process area
CPVC	Chlorinated polyvinyl chloride
CWA	Clean Water Act
DCB	Dichlorobenzene
DCE	Dichloroethene
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DNAPL	Dense non-aqueous phase liquid
DOD	Department of Defense
DOE	Department of Energy
DUS	Dynamic underground stripping
dyn/cm	Dynes per centimeter
EPA	U.S. Environmental Protection Agency
ERH	Electrical resistance heating
ET-DSP™	Electro-Thermal Dynamic Stripping Process
Farmer Brothers	Farmer Brothers Coffee Company
FLUTe	Flexible Liner Underground Technologies™

ACRONYMS AND ABBREVIATIONS

Abbreviation	Term
FS	Feasibility Study
ft/ft	Feet per foot
FTO	Flameless thermal oxidizer
FWPCA	Federal Water Pollution Control Act
GAC	Granular activated carbon
g/cc	Grams per cubic centimeter
GHG	Green house gas
gpd/ft	Gallons per day per foot
GRA	General response actions
GW	Groundwater
H+A	Hargis + Associates, Inc.
HD	Hydraulic displacement
ICs	Institutional controls
IGSM	Integrated global system model
ISCO	In-Situ chemical oxidation
ISGS	In-Situ groundwater standards
IPCC	Intergovernmental Panel on Climate Change
ISTD	In-Situ thermal destruction
JCI	Jones Chemical Inc.
J.O.D.	Joint Outfall D
JP-4	Jet propellant fuel
Kv	Vertical hydraulic conductivity
Kw-hr	Kilowatt- hour per cubic yard
LACSD	Los Angeles County Sanitation District
LADWP	Los Angeles Department of Water and Power
LBA	Lower Bellflower Aquitard
LGAC	Liquid-phase granular activated carbon
LNAPL	Light non-aqueous phase liquid
MM	Million
MCB	Monochlorobenzene
MCF	Thousand cubic feet
MCLs	Maximum contaminant levels

ACRONYMS AND ABBREVIATIONS

Abbreviation	Term
µg/L	Micrograms per liter
mg/kg	Milligrams per kilogram
MGP	Manufactured gas plant
MIT	Massachusetts Institute of Technology
µmhos/cm	Micromhos per centimeter
m/L	Milligrams per liter
ml/min	Milliliter per minute
mmHg	Millimeters of mercury
MNA	Monitored natural attenuation
Montrose	Montrose Chemical Corporation of California
MSL	Mean sea level
NAPL	Non-aqueous phase liquids
NCP	National Oil and Hazardous Substances Contingency Plan
NPL	National Priorities List
NPV	Net present value
OU	Operable unit
OVA	Organic vapor analyzer
PCE	Tetrachloroethene
pCBSA	Polychlorinated biphenols
PD	Playa Deposits
PDS	Passive diffusion bags
PEA	Preliminary Endangerment Assessment
PICS	Products of incomplete combustion
ppmv	Parts per million vapor
Lbs/hr	Pounds per hour
PPE	Personal protective equipment
PRG	U.S. EPA Preliminary Remediation Goals
PVS	Palos Verdes Sands
RA	Remedial Alternatives
RAOs	Remedial Action Objectives
RD	Remedial design
ROD	Record of Decision
ROI	Radius of influence
SCE	Southern California Edison

ACRONYMS AND ABBREVIATIONS

Abbreviation	Term
scfm	Standard cubic feet per minute
SEAR	Surfactant enhanced aquifer remediation
SEE	Steam enhanced extraction
Site	Montrose Superfund Site
SPH	Six phase heating
Stauffer	Stauffer Chemical Company
SREG	Smart Energy Resource Guide
SVE	Soil vapor extraction
T	Transmissivity
TBCs	To be considered
TCA	Trichloroethane
TCE	Trichloroethene
TCH	Thermal conductive heating
TEE	Thermal enhanced extraction
UBA	Upper Bellflower Aquitard
UN	United Nations
UNEP	United Nations Environmental Programme
UPRR	Union Pacific Railroad
UTCHEM	University of Texas Chemical Composition Simulator
VOC	Volatile Organic Compound
WBZ	Water bearing zone
WHO	World Health Organization

EXECUTIVE SUMMARY

This dense non-aqueous phase liquid (DNAPL) Feasibility Study (FS) is part of the remedial evaluation process being conducted for the Montrose Chemical Corporation of California (Montrose) Superfund Site (Site) located at 20201 S. Normandie Avenue, Los Angeles, California (**Figure 1.1**). Montrose leased a 13-acre Property from Stauffer Chemical Company (Stauffer) in 1947 and manufactured technical grade dichlorodiphenyltrichloroethane (DDT) at the Property from 1947 until 1982. A DNAPL composed of DDT and monochlorobenzene (MCB), a raw material used in the manufacturing process, has been detected in certain areas beneath the Site. This FS identifies and evaluates alternatives for the remediation of DNAPL at the Site and has been prepared in accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies under Comprehensive Environmental Response, Compensation, and Liability Act, Interim Final* (U.S. Environmental Protection Agency [EPA], 1988). This DNAPL FS was also prepared in accordance with requirements established in the Second Amendment to the Administrative Order on Consent, EPA Docket No. 85-04 (EPA, 1989a).

This section provides an executive summary of the following DNAPL FS information:

- The nature and extent of DNAPL occurrence at the Montrose Site (refer to Section 2.0 for more details);
- DNAPL treatability and modeling studies (refer to Section 2.6 for more details);
- DNAPL remedial action objectives (refer to Section 3.1 for more details);
- Assembly of candidate DNAPL remedial alternatives (refer to Section 5.0 for more details);
- Detailed evaluation and comparison of candidate DNAPL remedial alternatives (refer to Sections 6.0 and 7.0 for more details).

Nature of DNAPL

Because the Montrose DNAPL is composed of a VOC and a pesticide, the nature of the DNAPL is different from more common DNAPLs such as trichloroethene (TCE) and tetrachlorethylene (PCE). Montrose and EPA conducted independent evaluations of case sites in 2007, of up to 177 sites, and only one site was found to contain a VOC/pesticide DNAPL. Additionally, there were only four sites where MCB was a component of the DNAPL. Due to the infrequent occurrence of this type of DNAPL, the behavior of this DNAPL under varying conditions is not well documented, and there is an exceptionally limited basis from which to evaluate the success or failure of DNAPL remedial action at sites with these type of contaminants.

DNAPL Composition

Results of DNAPL sample analyses from 1998, 2008, and 2009 are provided in **Appendix A** and indicate that the Montrose DNAPL is typically composed of approximately 50% MCB by weight and 50% Total DDT by weight.

DNAPL Physical Properties

The physical properties of the Montrose DNAPL were evaluated during studies conducted in 1998 (H+A, 1999) and 2006 (H+A, 2006b; Davis, 2006) and are summarized as follows:

- The DNAPL co-boiling point (with water) is approximately 96°C at 1 atmosphere, which is relatively high compared with other VOCs and common DNAPLs;
- The DNAPL is approximately 25% more dense than water (1.25 g/cc at 20°C);
- The DNAPL is approximately 2.5 times more viscous than water (2.5 centipoise at 20°C);
- The DNAPL interfacial tension (with water) is low to moderate in comparison with other common DNAPLs (13 to 15 dynes per centimeter).

Considering all physical properties, the Montrose DNAPL exhibits a moderate mobility as compared with other common DNAPLs. Because of the higher boiling point (132°C at 1 atmosphere) and lower vapor pressure (12 millimeters of mercury at 20°C) of MCB, thermal remediation technologies that rely primarily on contaminant volatilization will be less effective for the Montrose DNAPL than for most other VOCs.

Lateral Extent of DNAPL

The lateral extent of DNAPL occurs fully within the Technical Impracticability Waiver Zone established by the EPA as part of the Groundwater ROD (EPA, 1999). In the unsaturated zone, the definite extent of DNAPL is estimated to be approximately 57,000 square feet and encompasses the majority of the Central Process Area (CPA) at the former Montrose plant. The possible extent of DNAPL in the unsaturated zone is estimated to be approximately 79,000 square feet.

DNAPL occurs over a larger area within the saturated zone than observed within the unsaturated zone. The definite presence of DNAPL in the saturated Upper Bellflower Aquitard (UBA) occurs over an area of approximately 150,000 square feet. DNAPL extends east of the former CPA, presumably due to DNAPL migration along the top of low permeability silt layers in the down-slope direction. The possible presence of DNAPL occurs over a larger area than the definite DNAPL and encompasses approximately 160,000 square feet.

Vertical Extent of DNAPL

DNAPL has been definitively detected from a minimum of 7 feet bgs in the unsaturated zone to a maximum of 101.5 feet bgs in the saturated UBA (H+A, 1999 and 2004b). The predominant DNAPL-impacted zone is the saturated portion of the UBA at depths ranging from approximately 75 to 95 bgs (H+A, 2004b). The majority of the observed DNAPL is perched on low permeability silt layers throughout the UBA.

The presence of DNAPL has not been confirmed in the Bellflower Sand (BFS) Aquifer underlying the UBA. Additional characterization activities were conducted in 2008 to investigate for the presence of DNAPL in the BFS at the Site (H+A, 2008b and 2008c). Increasing vertical concentration profiles were observed at well BF-9 and in discrete samples collected at boring BFSB-1, which could be indicative of DNAPL in the BFS. Concentrations at the base of the BFS at boring BFSB-1 were approximately 20% of the MCB solubility limit. If DNAPL is present within the BFS, it will provide a continuing source of MCB to groundwater regardless of the amount of DNAPL remediation accomplished within the overlying UBA. However, given the limited evidence of DNAPL occurrence in the BFS, the mass of DNAPL potentially present in the BFS would be significantly less than the mass occurring within the overlying UBA.

<u>Estimated DNAPL Mass in the Saturated Zone</u>

The DNAPL mass was estimated to be approximately 796,100 pounds as shown in **Appendix E** (H+A, 2008e). This mass estimate is based on the liberal DNAPL thicknesses presented in Section 2.5.4, the DNAPL concentrations presented in Section 2.5.3, and the area of DNAPL-impacts presented in Section 2.5.1. Using the measured density of the Montrose DNAPL at 22°C (1.25 g/cc), the equivalent volume of DNAPL occurring within the saturated UBA was estimated as follows:

- Mobile DNAPL mass is estimated to be roughly 221,800 pounds or 21,000 gallons (refer to Appendix E for more details);
- Residual DNAPL mass is estimated to be roughly 574,200 pounds or 55,000 gallons;
- Total DNAPL mass (mobile plus residual) is estimated at 796,100 pounds or 76,000 gallons.

<u>Estimated MCB Mass in the Unsaturated Zone</u>

The mass of MCB in the unsaturated zone was estimated as shown in **Appendix C** and summarized below:

- <u>Playa Deposits (0 to 25 feet bgs):</u> An estimated 237,000 pounds of MCB are present, including DNAPL-phase MCB.
- <u>Palos Verdes Sand/unsaturated Upper Bellflower Aquitard (25 to 60 feet bgs):</u> An estimated 261,000 pounds of MCB are present, including DNAPL-phase MCB.

Other VOCs occur in unsaturated soils in substantially lower concentrations and frequencies. Those VOCs are not components of DNAPL, they do not significantly contribute to the mass of VOCs at the Site, and they will not significantly impact remedial alternative analysis or the duration of necessary groundwater containment.

<u>DNAPL Treatability and Modeling Studies</u>

A series of studies, laboratory bench tests, and field pilot tests have been conducted to evaluate candidate DNAPL remedial technologies as described in Section 2.6 and summarized as follows:

- <u>Mass Flux Evaluation:</u> Hydraulic containment timeframes required under various assumed DNAPL mass reduction scenarios were estimated using numerical methods as described in Section 2.6.1 and **Appendix G**. Without any reduction in the DNAPL mass, hydraulic containment within the UBA will be required for nearly an estimated five millennia. Furthermore, the containment duration will not be meaningfully reduced even under various accelerated DNAPL mass reduction scenarios.
- <u>DNAPL Extraction Testing:</u> Three separate DNAPL extraction field pilot tests were conducted at the Site from 1991 to 2008 as described in Section 2.6.3 (H+A, 1999 and 2007c). Mobile DNAPL was extracted from five different wells screened in the UBA at rates up to 11 gallons per day, including well UBE-5 located east of the CPA adjacent to soil boring SSB-12.
- <u>Hydraulic Displacement Modeling:</u> The performance of a hydraulic displacement DNAPL remedy in the UBA was modeled using the University of Texas Chemical Composition Simulator (UTCHEM), Version 9 (H+A, 2009b) as described in Section 2.6.4. The revised modeling approach predicted that DNAPL would be effectively mobilized for capture at well spacings up to 120 feet (i.e., 60-foot single well capture radius). In addition, the model predicted that DNAPL would not penetrate through the UBA and into the underlying BFS, even under conservative

assumptions that maximized DNAPL accumulation over the basal silty sand layer in the UBA (DNAPL pool heights up to 8 feet).

- Soil Vapor Extraction (SVE) Field Pilot Test: A field pilot test to evaluate the feasibility of removing VOCs from unsaturated soils was conducted at the Property in 2003 (Earth Tech, 2004a) as described in Section 2.6.5. SVE was found to be a highly effective technology for removing MCB and other VOCs from permeable unsaturated soils within the Palos Verdes Sand (PVS) and unsaturated UBA. However, due to the low permeability of the soils and vertical communication with the underlying PVS, SVE was found to be significantly less effective within the Playa Deposits (PD).
- 2-Dimensional Steam Flushing Bench Study: A thermal technology bench-scale study was conducted by Dr. Brent Sleep with the University of Toronto to evaluate mobilization of the Montrose DNAPL under steam flushing. Run 1 of the 2-dimensional steam flushing experiments was conducted on January 8, 2009 as described in Section 2.6.6 and **Appendix K**. The Run 1 results indicate that only 42% of the original DNAPL mass and 64% of the original MCB mass was removed from the cell by steam injection, even though the sand layer reached target temperature throughout the cell and more than 3 pore volumes of steam (cold water equivalent) was flushed through the sand layer. Post-test analysis of soil in the cell indicated that elevated concentrations of MCB (up to 14,000 mg/kg) remained within the sand layer, and that DNAPL constituents migrated through the capillary barrier (potentially as a result of desaturation) and into soils underlying the capillary barrier.

DNAPL Remedial Action Objectives (RAOs)

RAOs were established for the DNAPL program following a series of technical meetings with EPA in 2007 and 2008, with the final RAOs established at a September 11, 2008 meeting as described in Section 3.1 and as follows:

1) Prevent human exposure to DNAPL constituents (via ingestion, inhalation, or dermal contact) that would pose an unacceptable health risk to on- or off-property receptors under industrial land uses of the Montrose plant property and adjacent properties;
2) To the extent practicable, limit uncontrolled lateral and vertical migration of mobile NAPL under industrial land use and hydraulic conditions in groundwater;
3) Increase the probability of achieving and maintaining containment of dissolved-phase contamination to the extent practicable, as required by the existing groundwater ROD, for the time period that such containment remains necessary;
4) Reduce NAPL mass to the extent practicable;
5) To the extent practicable, reduce the potential for recontamination of aquifers that have been restored by the groundwater remedial actions, as required by the groundwater ROD, in the event containment should fail; and
6) To the extent practicable, reduce the dissolved-phase concentrations within the containment zone over time.

Identification of the applicable or relevant and appropriate requirements (ARARs) and criteria to-be considered (TBCs) for DNAPL was accomplished by reviewing federal, state, and local laws, regulations, and policies. A determination of ARARs and TBCs was made based upon the terms of those statutes, regulations, and policies, consideration of EPA guidance, primarily the guidance entitled *CERCLA*

Compliance With Other Laws Manual: Interim Final (Parts I and II), EPA/540/G-89/006 (August 1989b), and discussions with EPA. The ARARs and TBCs for DNAPL are presented in Section 3.3.

Assembly of DNAPL Remedial Alternatives (RAs)

General Response Actions (GRAs) were identified in Section 3.2, and DNAPL remedial technologies and process options were preliminarily evaluated in Section 4. Following preliminary evaluation, retained DNAPL remedial technologies and process options were assembled into eight candidate RAs in Section 5 and described as follows:

Summary of Assembled Remedial Alternatives

Remedial Alternative	GRA Remedial Technologies/Process Options
Remedial Alternative 1	No Action Containment (required by Groundwater ROD)
Remedial Alternative 2	Containment (required by Groundwater ROD) Institutional Controls
Remedial Alternative 3	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone)
Remedial Alternative 4	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) Hydraulic Displacement, with untreated water injection
Remedial Alternative 5a	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) Steam Injection, focused treatment area, with hot floor
Remedial Alternative 5b	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) Steam Injection, entire treatment area, with hot floor
Remedial Alternative 6a	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) ERH, focused treatment area, without hot floor
Remedial Alternative 6b	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) ERH, entire treatment area, without hot floor

The above eight candidate RAs are described in Section 5.1 and were evaluated in Section 5.2. Following the intermediate screening, RAs 5b and 6b were eliminated from further consideration for the reasons identified in Sections 5.2.6 and 5.2.8 respectively.

Detailed Evaluation and Comparison of Candidate DNAPL RAs

The remaining six RAs were evaluated in Section 6 against the nine performance criteria defined by the National Contingency Plan (40 CFR 300.430 (e)(9)). The performance of the six RAs relative to the nine criteria was then compared in Section 7 and is summarized below:

Overall Protection of Human Health and the Environment

Moderately Protective: RA 1 is considered moderately protective unless institutional controls implemented through the soil remedy restrict site activities that present a potential for human exposure to DNAPL-impacted soils.

Protective: RAs 2 through 4 would protect human health by restricting Site access and uses that may result in exposure to DNAPL-impacted soils. RAs 3 and 4 would protect the environment by removing the source of VOCs and DNAPL in the permeable unsaturated zone (PVS and unsaturated UBA) overlying groundwater. RA 4 would protect the environment by removing mobile DNAPL from the saturated UBA by hydraulic displacement, reducing the risk of DNAPL migration either laterally within the UBA or downward into the BFS.

Protective (but higher risk): RAs 5a and 6a may be protective of human health and the environment but would present an increased risk of adverse consequences associated with remedy excursion or upset conditions. There is an increased risk of contaminant migration associated with thermal remediation, particularly steam injection. Although RA 5a includes implementation of a hot floor within the underlying BFS, the effectiveness of a steam injection hot floor in the underlying aquifer is uncertain. Further, installation of a hot floor presents drilling-related risks of contaminant migration, and a hot floor has not been implemented at a comparable site. Also, a significant amount of greenhouse gases (GHG) would be emitted to the environment as a result of RAs 5a and 6a, contributing to global warming. In a proposed finding dated April 17, 2009, EPA concluded that greenhouse gases, including carbon dioxide, endanger the public health and welfare of current and future generations.

Compliance with ARARs

Does Not Comply: RA 1 would not comply with DNAPL ARARs, unless institutional controls implemented through the soil remedy address DNAPL exposure pathways.

Complies: RAs 2, 3, and 4 would comply with ARARs. RAs 3 and 4 include SVE with ex-situ vapor treatment, and field pilot testing has already demonstrated the ability of disposable carbon to comply with air emission ARARs. RAs 1 through 4 have either a zero or relatively small carbon footprint and would comply with EPA green remediation initiatives and the California Global Warming Solutions Act of 2006.

Complies, except for GHG TBCs: RAs 5a and 6a would comply with ARARs, except for the global warming TBCs. The thermal remediation components of RAs 5a and 6a require a large amount of energy to implement. As a result, the GHG emissions and carbon footprints for these remedies are high, approximately 10 to 20 times higher than RAs 3 and 4. Given the Obama Administration's commitment to reducing GHG emissions, the recently proposed EPA GHG reporting policy (March 2009), and numerous GHG bills introduced in Congress that are likely to ultimately result in a national cap-and-trade regime, the importance of selecting remedies that meet these TBCs is expected to increase.

Long-Term Effectiveness and Permanence

Moderately Effective: RAs 1 and 2 are considered moderately effective in the long-term because these RAs do not include source area VOC or DNAPL mass reduction. Under RAs 1 and 2, long-term effectiveness would be achieved through the hydraulic containment component of the remedies, which would be required for an estimated four to five millennia.

Effective: RAs 3 and 4 are considered effective in the long-term because MCB mass, specifically mobile MCB mass in the case of RA 4, is removed in the short-term, thereby increasing the probability of achieving and maintaining hydraulic containment in the long-term. Under RAs 3 and 4, MCB mass in the unsaturated zone is removed by SVE. Under RA 4, mobile DNAPL-phase MCB mass in the saturated zone is removed by hydraulic displacement. The duration required for hydraulic containment would not be meaningfully reduced under RAs 3 and 4.

Effective (but with risks): RAs 5a and 6a will remove MCB mass in the short-term by steam injection and ERH, but as indicated in Sections 6.2.5 and 6.2.6, these RAs present increased risks of contaminant mobilization, which could negatively affect the long-term effectiveness of the hydraulic containment remedy component. Although RAs 5a and 6a have the potential to remove the most MCB mass, the estimated timeframe required for hydraulic containment would not be meaningfully reduced by these remedies.

Reduction of Toxicity, Mobility, and/or Volume of Hazardous Constituents

In the long-term, all of the RAs would reduce both the volume and mobility of the DNAPL in the saturated UBA via dissolution and hydraulic containment. In the short-term, DNAPL mass would be reduced by the RAs as summarized below:

Estimated MCB/DNAPL Mass Removal in Short-Term

	Unsaturated Zone Estimated Mass Removal (lbs) 261,000 lbs MCB Present	Saturated UBA Estimated Mass Removal (lbs) 221,800 lbs Mobile DNAPL Present (RA 4)* 236,800 lbs MCB in DNAPL-phase (RAs 5a and 6a)*			Estimated Mass Removal Total for Unsaturated and Saturated Zones
Assumed Removal Efficiency →	95%	80%			
DNAPL Component →	MCB	MCB	DDT	Total	Total
RA 1	0	0	0	0	0
RA 2	0	0	0	0	0
RA 3	248,000	0	0	0	248,000
RA 4	248,000	88,700	88,700	177,400	425,500
RA 5a	248,000	189,500	>0	>189,500	>437,500
RA 6a	248,000	189,500	0	189,000	437,500

Notes:
* = in Focused Treatment Area; MCB assumed to be 50% of total DNAPL mass; excludes dissolved-phase mass
RA 4a will remove liquid-phase DNAPL consisting of both MCB and DDT.
RA 5a and 6a will remove primarily MCB, volatile component of DNAPL; RA 5a will remove some DNAPL-phase DDT (>0); unable to estimate more precisely.

Reduction of DNAPL mobility is an RAO for this FS, and the above mass removal table does not distinguish between mobile and residual DNAPL. Therefore, the estimated mass of mobile DNAPL removed by the candidate RAs is summarized as follows:

Estimated Mobile DNAPL Mass Removal in Short-Term

	Saturated UBA Estimated Mobile DNAPL Mass Removal (lbs) 221,800 lbs Mobile DNAPL Present		
Assumed Removal Efficiency →	80%		
DNAPL Component →	MCB	DDT	Total
RA 1	0	0	0
RA 2	0	0	0
RA 3	0	0	0
RA 4	88,700	88,700	177,400
RA 5a	<110,900	>0	<110,900
RA 6a	<110,900	0	<110,900

Notes:
RAs 5a and 6a will remove less than 100% of the mobile MCB mass
RA 5a will remove some DNAPL-phase DDT (>0); unable to estimate more precisely

Thermal remediation RAs 5a and 6a would primarily remove the volatile component of the DNAPL (i.e., MCB), leaving the majority of the DDT in-situ. However, RA 4 would remove mobile DNAPL-phase DDT and would likely remove the most mobile DNAPL of all RAs under consideration. RA 4 would also significantly reduce DNAPL mobility. Although RAs 5a and 6a would reduce DNAPL mobility in the long-term, thermal remediation increases DNAPL mobility in the short-term.

Short-Term Effectiveness

Moderately Effective: Although RA 1 does not include institutional controls for DNAPL-impacted soils, the institutional controls required for the soil and groundwater remedies will overlap the DNAPL-impacted soils to some degree resulting in a moderate level of protection for the No Action RA.

Effective: RAs 2, 3, and 4 would protect human health and the environment in the short-term by institutional controls. RAs 3 and 4 would additionally protect human health and the environment during SVE by treating soil vapors ex-situ with disposable carbon/resin. Disposable carbon/resin is the least complex vapor treatment technology and is a reliable method for protecting human health and the environment during remedy implementation. To ensure protection of human health and the environment in the short-term under RA 4, DNAPL extracted by hydraulic displacement would be collected in a dual-contained tank with engineering controls to prevent over-filling and automatically detect leaks.

Effective (but higher risk): RAs 5a and 6a would potentially be effective in protecting human health and the environment in the short-term but have higher risks associated with remedy excursions. Displaced DNAPL, contaminated steam condensate, and heated MCB vapors must be effectively recovered in order to prevent contaminant migration in the subsurface, either laterally outside the focused treatment area or downward into the underlying BFS. With thermal remediation, there is also an increased potential for heated vapors or contaminated steam to be accidentally released to atmosphere as a fugitive emission[1]. Fugitive emissions, if any, during remedy implementation would reduce the protectiveness of RAs 5a and 6a in the short-term.

[1] Such accidental fugitive emissions were experienced at the Silresim Superfund Site and SCE Visalia Site.

Implementability

Implementable: RAs 1 and 2 are readily implementable and require little or no infrastructure. Access restrictions are already being implemented at the Site, and a Land Use Covenant could be established at the Montrose Property, where nearly all of the DNAPL is located. RAs 3 and 4 are also implementable. SVE is a widely implemented technology, and disposable carbon/resin is readily available for ex-situ vapor treatment. The implementability of hydraulic displacement has already been demonstrated through field pilot testing, with moderate DNAPL recovery rates observed in all wells within the mobile DNAPL footprint. The Montrose DNAPL can be readily separated from groundwater using standard techniques, which enhances the implementability of hydraulic displacement.

Difficult To Implement: RAs 5a and 6a would be more difficult to implement than the other RAs. Thermal remediation projects require a large amount of infrastructure to heat the subsurface, recover contaminants, and treat or dispose of contaminants ex-situ. A large number of wells are required for thermal remediation projects and would generate a significant amount of waste requiring management and disposal, particularly for RAs including a hot floor in the BFS. Under RAs 5a and 6a, ex-situ treatment of groundwater with subsequent re-injection off-Property into the BFS and Gage Aquifer would be required. RAs 5a and 6a would additionally require a high level of maintenance, highly skilled field operators, and specialized technology vendors (that are licensed for steam injection). In addition, a limited number of vendors are still pursuing steam injection as a commercial technology and only one vendor (TerraTherm) has sufficient resources to potentially implement a project of this size.

Cost

Estimated costs for the six candidate RAs ranged from $1.1 to $25.8 MM NPV as follows:

Cost Ranking

RA	Components	Cost Rank	Estimated NPV Cost	Unit NPV Cost
RA 1	No Action, HC	No Cost	$1.1 MM	NA
RA 2	HC, ICs	Low	$1.3 MM	NA
RA 3	HC, ICs, SVE	Low to Moderate	$5.9 MM	$19/lb removed by SVE
RA 4[1]	HC, ICs, SVE, HD	Moderate	$11.7 MM	$33-$40/lb removed by HD
RA 5a[2]	HC, ICs, SVE, Steam Injection over focused treatment area with hot floor	High	$24.6-$25.8 MM	$110-$116/lb removed by steam injection
RA 6a[2]	HC, ICs, SVE, ERH over focused treatment area without hot floor	High	$21.2-$22.9 MM	$92-$101/lb removed by ERH

Notes:
NA = not applicable; no mass reduction in short-term
Unit cost reflects NPV cost of remedial component (i.e., SVE, HD, steam, or ERH) divided by estimated mass reduction in pounds (lb); unit cost does not reflect sum of all remedy components.
All RAs include costs for long-term hydraulic containment (HC), including RA 1.
[1]HD costs reflect an assumed range for well spacing.
[2]In accordance with EPA cost reconciliation discussions, the estimated cost for RAs 5a and 6a includes both low and high cost scenarios consistent with an assumed range for energy consumption and well spacing.

RAs 1 and 2, with no DNAPL mass reduction in the short-term, are the lowest cost RAs under consideration ($1.1 to $1.3 MM NPV). RA 3 has a low to moderate total cost ($5.9 MM NPV) and has the lowest unit cost at approximately $19 per pound of contaminant removed by SVE from the unsaturated zone. Of the three candidate RAs which reduce DNAPL mass in the saturated zone (i.e., RAs 4, 5a, and 6a), RA 4 has both the lowest total and unit cost. RA 4 has a moderate total cost ($11.7 MM NPV) and an estimated unit cost of $33 to $40 per pound of contaminant removed by hydraulic displacement. RAs 5a and 6a are the two highest cost alternatives ($21.2 to $25.8 MM NPV) and have estimated unit costs of $92 to $116 per pound of contaminant removed by thermal remediation.

State Acceptance

This criterion cannot be evaluated until the State has commented on the draft DNAPL FS and Proposed Plan. Therefore, evaluation of this criterion is deferred and will be addressed by EPA in the ROD.

Public Acceptance

<u>May Accept:</u> RAs 1 and 2 are most likely to be acceptable to the public. Under these RAs, no accelerated VOC or DNAPL mass reduction would take place. None of the hazardous constituents are brought to surface for ex-situ treatment, collection, or handling. RAs 3 and 4 may also be acceptable to the public. Ex-situ soil vapor treatment by disposable carbon/resin is a treatment technology that has been accepted by the public at other Superfund Sites. This treatment technology does not include combustion processes capable of generating dioxins or furans. Through field pilot testing, the activated carbon has been shown to be highly effective in treating vapor-phase contaminants at the Site.

<u>May Not Accept:</u> RAs 5a and 6a may not be accepted by the public. These thermal remediation technologies have the greatest potential for upset conditions, excursions, and fugitive emissions. The public may also not accept RAs 5a and 6a because of the high greenhouse gas emissions and contribution to global warming. Additionally, under RAs 5a and 6a, steam-regenerable carbon/resin or thermal oxidation would be used for ex-situ vapor treatment, which may not be as acceptable to the public as the disposable carbon/resin would be for RAs 3 and 4. Finally, the public may not accept RAs 5a and 6a due to the increased risks of contaminant mobilization in the subsurface, either laterally within the UBA or vertically downward into the underlying BFS.

<u>Montrose Preferred RA</u>

RA 4 is identified as the Montrose preferred RA for DNAPL. RA 4 includes four components:

- Hydraulic containment (long-term)
- Institutional controls
- SVE in the permeable unsaturated zone (short-term)
- Hydraulic displacement in the saturated UBA (short-term)

The first two remedy components, hydraulic containment and institutional controls, protect human health and the environment both in the short and long-term. Fundamental compliance with the NCP threshold criteria are met by these two remedy components in the long-term. The second two remedy components, SVE and hydraulic displacement, reduce DNAPL mass and mobility in the short-term, which are RAOs for DNAPL at the Site. SVE reduces VOC/DNAPL mass and mobility in the unsaturated zone, while hydraulic displacement reduces DNAPL mass and mobility in the saturated UBA.

RA 4 meets DNAPL RAOs, complies with ARARs, and protects human health and the environment. RA 4 is *(i)* effective in both the short and long-term; *(ii)* the most implementable technology of the three RAs that reduce DNAPL mass/mobility in the saturated UBA (i.e., RAs 4, 5a, and 6a); and *(iii)* reduces DNAPL mass and mobility in both the unsaturated and saturated zones at a much lower cost than RAs 5a and 6a. Indeed, RA 4 is less costly than RAs 5a and 6a and will likely remove the most mobile DNAPL of the three, making it the most cost-effective mass/mobility reduction RA. The estimated unit cost for hydraulic displacement under RA 4 ($33 to $40 per pound of contaminant removed) is less than half the estimated unit cost for thermal remediation under RAs 5a and 6a ($92 to $116 per pound of contaminant removed).

Further, RAs 5a and 6a will not meaningfully reduce the duration of necessary groundwater containment beyond the containment timeframe estimated for RA 4. Additionally, RA 4 is less complex, less uncertain, and has significantly less risk than RAs 5a and 6a. RA 4 is also expected to be acceptable to the public and would generate significantly fewer greenhouse gases than the candidate thermal remediation alternatives (RAs 5a and 6a). For these reasons, the Montrose preferred remedy for DNAPL is RA 4.

Section 1.0

Introduction

1.0 INTRODUCTION

This dense non-aqueous phase liquid (DNAPL) Feasibility Study (FS) is part of the remedial evaluation process being conducted for the Montrose Chemical Corporation of California (Montrose) Superfund Site (Site) located at 20201 S. Normandie Avenue, Los Angeles, California (**Figure 1.1**). A DNAPL composed of monochlorobenzene (MCB) and dichlorodiphenyltrichloroethane (DDT) has been detected beneath the Site. This FS identifies and evaluates alternatives for the remediation of DNAPL at the Site and has been prepared in accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies under Comprehensive Environmental Response, Compensation, and Liability Act, Interim Final* (U.S. Environmental Protection Agency [EPA], 1988). In general, the FS process begins with a preliminary evaluation of remedial technologies to screen out those that are not, at a minimum, moderately effective and implementable. The retained technologies are then assembled into a series of remedial alternatives with each successive alternative potentially providing a greater degree of environmental restoration. These assembled alternatives are evaluated against a set of nine criteria and then compared, relative to their ability to meet the performance criteria. This FS provides a mechanism by which EPA can evaluate the technologies and remedial alternatives for DNAPL at the Montrose Superfund Site.

Montrose submitted a prior version of the DNAPL FS to EPA in September 1999 (Hargis + Associates, Inc. [H+A], 1999). EPA subsequently requested that additional testing be conducted to further characterize the nature and extent of DNAPL at the Site and to evaluate candidate technologies through laboratory and field pilot studies. Montrose conducted additional DNAPL-related testing at the Site during the period 2003 through 2008, and sufficient data now exist for re-evaluation of the DNAPL remedial alternatives. This DNAPL FS supersedes the prior 1999 version and serves to evaluate candidate technologies and alternatives for the remediation of DNAPL at the Site. This DNAPL FS was prepared in accordance with requirements established in the Second Amendment to the Administrative Order on Consent, EPA Docket No. 85-04 (EPA, 1989a).

This section of the report defines terms for use in the FS and establishes the purpose and organization of the FS. This section additionally provides background information regarding the manufacturing history at the Site, current Property features, and a chronological summary of DNAPL characterization activities. Additionally, this section describes the geology and hydrogeology beneath the Site, both regionally and locally.

1.1 DEFINITION OF TERMS

For purposes of clarification, several terms are used in this DNAPL FS as defined below:

- The "Property" refers to the Montrose Property, not the entire Superfund Site, and encompasses the area within the fenced property located at 20201 South Normandie Avenue, Los Angeles, California.

- The "Site" refers to the entire Montrose Superfund Site, which includes the Montrose property and other areas.

- The term "Central Process Area" or CPA refers to an approximate 2-acre portion of the Montrose Property where most of the technical grade DDT manufacturing operations were historically conducted.

- The term "DNAPL" refers to a dense non-aqueous phase liquid; i.e., a liquid which is immiscible with and has a density greater than water. For this FS, the term DNAPL refers specifically to the Montrose DNAPL which is composed of MCB and DDT. The term DNAPL does not refer to MCB dissolved in groundwater.

- The term "NAPL" refers to any non-aqueous phase liquid, either a DNAPL or light non-aqueous phase liquid (LNAPL).

- The term "RI" refers to the Remedial Investigation Report (EPA, 1998).

- The term Total DDT refers to the sum of concentrations reported for 2,4' and 4,4' isomers of DDT, DDE (dichlorodiphenyldichloroethylene), and DDD (dichlorodiphenyldichloroethane).

- The term "DNAPL concentration" refers to the sum of concentrations reported for MCB and Total DDT in soil containing DNAPL. In soils not containing DNAPL, MCB and Total DDT may also occur but not in DNAPL-phase (and therefore not as a DNAPL concentration). Additional details regarding DNAPL characterization methods are provided in Section 2.5.

- The term "mobile DNAPL" refers to DNAPL that occurs in sufficiently high saturations as to flow through soil pores under gravity or hydraulic displacement.

- The term "residual DNAPL" refers to DNAPL that occurs in low saturations, is bound in the soil pores by capillary forces, and is not mobile under gravity or hydraulic displacement.

- The term "definite DNAPL" refers to the definitive occurrence of DNAPL at an investigation boring or sample. Additional details regarding the occurrence of DNAPL at the Site are provided in Section 2.5.

- The term "possible DNAPL" refers to the possible occurrence of DNAPL, which is not definitive, at an investigation boring or sample.

- The term "DNAPL-impacted area" refers to the area encompassing definite or possible DNAPL at the Property.

- The term "DNAPL architecture" refers to the spatial distribution and occurrence of DNAPL within porous media in the form of either ganglia or pools.

1.2 PROJECT BACKGROUND

This section briefly describes the location and manufacturing history of the Site. More detailed discussions of the Site location and historical Montrose operations at the Property are provided in the *Final Remedial Investigation Report for the Montrose Superfund Site* (EPA, 1998). The historical Site features described in this section are primarily limited to raw materials storage, specifically MCB, and manufacturing operations that ultimately were the source of DNAPL subsequently found in subsurface soils at the Property.

Site Location

The Montrose Property is located at 20201 South Normandie Avenue in the City of Los Angeles, California (**Figure 1.2**). The Site is located within a portion of the City of Los Angeles identified as the Harbor Gateway, which extends from Western Avenue to Normandie Avenue. The City of Torrance is located west of the Harbor Gateway, and unincorporated Los Angeles County is located east of the Harbor Gateway.

The Montrose Property occupies approximately 13 acres and is bounded by the Union Pacific Railroad (UPRR) right-of-way and Normandie Avenue to the east, the Jones Chemical Inc. (JCI) property and a right-of-way owned by the Los Angeles Department of Water and Power (LADWP) to the south, the former Boeing Realty Corporation property to the north, and Frito-Lay, Inc. to the west. The Farmer Brothers Coffee Company (Farmer Brothers) property is located to the south of the LADWP right-of-way.

The land use up to approximately one mile north and east of the Property, and approximately one half mile to the west, is zoned for industrial and commercial use. The areas east of the Property is occupied by manufacturing and commercial facilities. The area to the west is occupied by manufacturing and an oil refinery. Land uses south and southeast of the Property are mixed manufacturing, commercial, and residential zoning. In a 2004 study conducted by EPA (EPA, 2004a), it was concluded that the most likely re-use scenario for the Montrose Property would be for industrial purposes, conforming with current zoning, surrounding property use, and the *Harbor Gateway Community General Plan* (City of Los Angeles, 1996).

Manufacturing History

Montrose leased the 13-acre Property from Stauffer Chemical Company (Stauffer) in 1947 and manufactured technical grade DDT at the Property from 1947 until 1982. Montrose manufactured DDT by combining MCB and chloral in the presence of a powerful sulfuric acid catalyst (oleum). A number of processing steps then occurred to separate the DDT from the acid and residual raw materials; neutralize and purify the DDT; and crystallize the DDT to solid form. The solid DDT was then either bagged, or ground and bagged for sale. The Montrose plant produced as much as eighty million pounds of technical grade DDT annually. Montrose supplied technical grade DDT to, among others, the Department of Defense (DOD), United Nations (UN), and the World Health Organization (WHO).

Historical features associated with the Montrose DDT plant are shown in **Figure 1.3**. An aerial photograph of the plant from 1965 is shown in **Figure 1.4**. Most operations took place in the CPA. This portion of the Property is a rectangular area approximately 270 feet by 400 feet where the processing building, processing equipment, water recycling pond, electrical transformer station, filtration area, acid recovery plant, and several above- and below-ground tanks were located. The formulating and grinding plant, Warehouse No. 3, was built in 1964 directly south of the CPA and operated continuously from 1964 to 1982. Two 25,000-gallon, below-ground, redwood-lined, concrete tanks were installed in 1953 to store wastewater and were located near the southeastern corner of the CPA.

Raw materials consisting of MCB, chloral, and oleum were stored in aboveground tanks located in or near the CPA. Initially, raw material storage consisted of four 10,000-gallon tanks that contained (1) MCB, (2) oleum, (3) a mixture of MCB and chloral, and (4) spare oleum. All four tanks were located aboveground in the northeast quadrant of the CPA. An additional 10,000-gallon tank was added in 1950 to store a mixture of MCB and chloral. A 17,000-gallon tank was added in 1965 to store MCB. Both of these additional tanks were located aboveground in the northeast quadrant of the CPA. In 1968, the rail spur was modified; and two 50,000-gallon aboveground storage tanks were installed east of the formulating and grinding plant to allow transport of chloral and MCB via tank car. Dikes were constructed around these two tanks as a safety measure. In approximately January 1975, Montrose installed a 100,000-gallon aboveground fuel oil storage tank and related accessories west of the process building.

In addition to the Montrose operations, Stauffer operated a small benzene hexachloride (BHC) plant on the southeast corner of the Property from approximately 1954 until 1963 when the plant was dismantled and removed from the Site. Benzene was a feedstock in the production of BHC and was stored on the

Property in a 5,000-gallon aboveground tank situated on a concrete pad. The benzene was trucked to the tank and then delivered from the tank to the plant through aboveground piping. Stauffer also operated a sulfuric acid manufacturing plant adjacent in the southwestern portion of the Site where JCI is currently located. The sulfuric acid plant was operated from the early 1940s until approximately 1952. The sulfuric acid plant was dismantled after 1965. No DDT manufacturing operations occurred at the JCI property, and to date, no DNAPL has been detected in subsurface soils at that Property. However, additional investigation of the JCI property is proposed, including investigation for the presence of DNAPL (Levine-Fricke, 2008), although Montrose is not responsible for contaminants relating to JCI operations.

Montrose terminated its production process on or about July 2, 1982. By August 1982, Montrose had completely ceased operating the plant. The plant was fully dismantled and demolished by early 1983. EPA proposed the Site for the Superfund National Priorities List (NPL) in 1984, and the proposal was finalized in 1989.

1.3 PRESENT PROPERTY FEATURES

In 1985, the Montrose Property was re-graded and capped with asphalt to prevent exposure to underlying shallow soils impacted with DDT. Two large raised building pads were constructed at the Property as shown in **Figure 1.5**. Building Pad A is located in the eastern portion of the Property and is approximately 5 to 6 feet thick. Building Pad B is located in the central portion of the Property and is approximately 6 to 7 feet thick. Building Pad B is divided into two halves by a stormwater channel. The asphalt surface is sloped for stormwater drainage from an elevation of approximately 45 feet above mean sea level (MSL) in the northwest corner to approximately 40 feet MSL in the southeast corner of the Property.

During re-grading activities, concrete foundations and footings were either left in place, buried in debris pits and trenches, or crushed and used as aggregate beneath the asphalt cover. The types and locations of buried concrete debris at the Property were documented in a report entitled *Buried Concrete Debris Evaluation* (Earth Tech, 2003). The locations of buried concrete debris at the Property are shown in **Figure 1.6**.

A total of six temporary soil and debris containment cells are located in the western portion of the Property as shown in **Figure 1.5**. The cells were constructed by EPA to temporarily contain DDT-impacted soils and debris excavated from the historic stormwater pathway located along Kenwood Avenue, southeast of the Property. Five of the cells were constructed in 2001/2002, and one cell was constructed in 2008. The soils and debris contained in the cells will ultimately be incorporated into the soil remedial alternative selected for the Site. Until that time, the soil cells will remain in place and be inspected regularly to ensure effective containment of the soil and debris. EPA is maintaining the soil cells and the ultimate disposition of the stored soils is the responsibility of EPA (EPA, 2002). An aerial photograph from 2008, showing the present Property features, is provided as **Figure 1.7**.

Entrance to the Property is via South Normandie Avenue through a locking gate situated at the northeast corner of the Property (**Figure 1.5**). To prevent public access, chain link fencing with razor wire has been erected along the northern, western, and southern Property boundaries, and a wrought iron fence with razor wire bounds the east side of the Property. A former guard shack is located adjacent to the front gate in the northeast corner of the Property. Additionally, there are two storage containers on-site for storage of field equipment and supplies. Water service is available through a metered line located at the northeast corner of the Property. Electrical and telephone services are not available at the Property. The Property remains vacant today.

Two sewer mains, the District 5 Interceptor and the Joint Outfall D (J.O.D.), run north to south beneath the eastern portion of the Property (**Figure 1.5**). The District 5 Interceptor is located approximately 50 feet west of the eastern Property boundary and is 62-inches in diameter. The J.O.D. is located approximately 30 feet west of the eastern Property boundary and is 57-inches in diameter. After 1953, Montrose discharged to the J.O.D sewer main through an 18-inch diameter sewer pipe (EPA, 1998). DDT-impacted sewer sediment was removed from the J.O.D. sewer main in 1996 and 1998 under EPA oversight (Earth Tech, 1999a). Prior to 1953, a 10-inch diameter sewer line ran from the former Montrose water recycling pond in the CPA to the East Torrance Extension Trunk located near the southwestern corner of the JCI property. Discharge to the 10-inch line was discontinued in 1953, and LACSD reported that the East Torrance Extension Trunk was abandoned in place in 1959 (LACSD, 1968).

1.4 REGIONAL HYDROGEOLOGIC FEATURES

A general description of the regional hydrogeologic features in the area surrounding the Site is provided below.

1.4.1 REGIONAL PHYSIOGRAPHY

The site is located on the Torrance Plain, which is a portion of the Los Angeles Coastal Plain (Coastal Plain) as shown in **Figure 1.8** (California Department of Water Resources [CDWR], 1961). The physiographic features of the Coastal Plain are the Torrance and Long Beach Plains, the El Segundo Sand Hills, the Dominguez and Alamitos Gaps, and portions of the Baldwin Hills, Rosecrans Hills, Dominguez Hill, Signal Hill, and the Palos Verdes Hills. The Baldwin Hills, Rosecrans Hills, Dominguez Hill, and Signal Hill are the surface expression of the Newport-Inglewood Uplift.

1.4.2 REGIONAL STRATIGRAPHY

The site is located within the West Coast Basin in the Torrance Plain. The basin is bounded on the north by the Ballona Escarpment, on the east by the Newport-Inglewood Uplift, on the southwest by the Palos Verdes Hills, and on the west by the Pacific Ocean (**Figure 1.8**). There are four major structural features in the vicinity of the site within the Torrance Plain. These features are the Charnock Fault, the Palos Verdes Fault, the Torrance Anticline, and the Gardena Syncline (CDWR, 1961).

The stratigraphy of the West Coast Basin includes Quaternary age continental and marine deposits and Tertiary age marine sediments overlying a basement complex of igneous and metamorphic rocks. The geologic units of hydrogeologic interest are, in order from oldest to youngest: the Pico Formation, the San Pedro Formation, the Lakewood Formation, older dune sand, alluvium, and active dune sand.

1.4.3 REGIONAL HYDROGEOLOGY

The Site is located in the groundwater basin known as the West Coast Basin (**Figure 1.8**). The West Coast Basin is located immediately west of the Newport-Inglewood Uplift. Pleistocene age and older formations have been downwarped forming the West Coast Basin. Groundwater in the West Coast Basin occurs in aquifers of varying water quality and usage. The principal aquifers at and in the vicinity of the Site are, in order from shallowest to deepest, the Gage aquifer, the Lynwood Aquifer, and the Silverado Aquifer (CDWR, 1961).

Regionally, the aquifers are primarily replenished with fresh water injected at two saltwater intrusion barrier projects located near the Pacific Ocean. The only significant source of natural replenishment comes from the Central Basin across the Newport-Inglewood Uplift. Injection barrier projects and pumpage primarily control water levels and flow directions within the basin. In the West Coast Basin, the base of the fresh water occurs at approximately 1,300 feet below MSL.

Hydrogeologic units in the West Coast Basin include aquitards and aquifers of varying compositions and water-yielding properties. These units, in order from first water encountered to deeper units, include the Bellflower aquitard (includes upper and lower aquitards, plus intermediate sand layer), the Gage aquifer, the Gage/Lynwood aquitard, the Lynwood aquifer, the Lynwood/Silverado aquitard, and the Silverado aquifer (**Figure 1.9**). Additional description of the site-specific stratigraphy is found in Section 1.5.1, and site-specific hydrogeology including groundwater flow direction, gradients, and hydraulic properties is provided in Section 1.5.2.

1.5 LOCAL HYDROGEOLOGIC FEATURES

A description of the hydrogeologic features beneath the Site is provided below, with an emphasis on the zones impacted by DNAPL. At the Site, DNAPL primarily occurs in the unsaturated zone and upper water-bearing zone, the Upper Bellflower Aquitard (UBA). Emphasis is placed on these stratigraphic units in this DNAPL FS. Stratigraphic units below the Bellflower Sand, such as the Gage and Lynwood Aquifers, are not impacted by DNAPL and are not discussed in detail in this FS.

1.5.1 STRATIGRAPHY

The stratigraphy of the Site is summarized below and is based on information provided in the 1998 Remedial Investigation (RI) Report (EPA, 1998) and subsequent characterization activities including the 2003/2004 DNAPL reconnaissance program (H+A, 2004b), the 2003 soil vapor extraction (SVE) pilot test (Earth Tech, 2004a), and the 2008 2-dimensional bench-scale studies (Earth Tech, 2008a). During the latter two characterization events, soil samples were specifically collected for physical properties analyses from stratigraphic units impacted with DNAPL. Physical properties results for unsaturated zone soils and the saturated UBA are provided in **Tables 1.1 and 1.2,** respectively. However, the physical properties data presented in these tables are based on a limited data set and do not account for potential variance throughout the Site.

A generalized stratigraphic column showing the various hydrologic units beneath the Property is provided as **Figure 1.9**. The nomenclature of the hydrologic units at the nearby Del Amo Superfund Site is slightly different and is additionally shown in this figure. However, the nomenclature used at the Del Amo Superfund Site will not be used for this FS. Because DNAPL occurs only at the Montrose Property and generally within the unsaturated zone and saturated UBA, use of this alternate nomenclature for deeper hydrologic units is not required in this FS. A cross-section location map and cross-sections illustrating the stratigraphy at the Site are provided in **Figures 1.10 through 1.13**. The information included in these cross-sections is based primarily on detailed soil descriptions from continuous core logged during Site characterization activities.

Unsaturated Zone (0-60 feet bgs)

The unsaturated zone at the Property occurs from land surface to approximately 60 feet below grade surface (bgs). The upper 1 to 4 feet at the Property is generally composed of reworked or fill-type materials and debris. Below the surficial layer of reworked materials, the unsaturated zone is characterized as having three generalized soil layers identified, from upper to lower, as Playa Deposits (PD), Palos Verdes Sands (PVS), and the unsaturated UBA. Each of these layers is individually described below. The depth intervals indicated are generalized and vary across the Property to some degree.

Reworked Materials (0-4 feet bgs)

Reworked or fill-type material consisting of moderately to highly plastic dark brown clayey silt, silty clay, or clay is generally encountered from ground surface to between 1 and 4 feet bgs in most areas of the Property. The reworked material additionally contains some construction debris consisting of concrete, brick, gravel, and wood. The thickness of the reworked materials is thicker within the raised building pads, between approximately 5 and 7 feet. Within the buried concrete debris trenches and pits, reworked materials are present to approximately 15 feet bgs (Earth Tech, 2003).

Playa Deposits (4-25 feet bgs)

The PD occurs from approximately 4 to 25 feet bgs at the Property and is primarily composed of medium brown, moist, dense silts, with some sand and clay. In 2003, the physical properties of PD soils were measured during an SVE pilot test conducted within the CPA at EW-1 (**Figure 1.14**), and the average properties from three samples were reported as follows (Table 1.1):

- % sand = 22.7%
- % silt/clay = 77.3%
- Dry bulk density = 1.48 grams per cubic centimeter (g/cc)
- Moisture content = 18.4%
- Total porosity = 45.1%
- Effective porosity = 17.3%
- Horizontal permeability to air = 12 millidarcies or 1.1×10^{-05} centimeters per second (cm/s)

Soils in the PD exhibit a relatively low horizontal permeability to air and have a moderate moisture content. Soils in the PD are also characterized as having a relatively high total porosity but a substantially lower effective or interconnected porosity.

Palos Verdes Sand (25-45 feet bgs)

Soils in the PVS are primarily composed of light yellowish brown to light olive-brown, well sorted sand. At the Property, the PVS is generally encountered from approximately 25 to 45 feet bgs. Thin well-cemented fossiliferous sand is encountered at the base of the PVS. This cemented fossiliferous sand is thickest in the western portions of the Property (up to 8 feet) and appears to dip slightly and thins to less than 2 feet to the east (**Figure 1.11**). The average physical properties of PVS soils, as measured during the 2003 SVE pilot test from three samples, are summarized as follows (Table 1.1):

- % sand = 77.2%
- % silt/clay = 22.8%
- Dry bulk density = 1.43 g/cc
- Moisture content = 6.2%
- Total porosity = 45.9%
- Effective porosity = 31.2%
- Horizontal permeability to air = 2,437 millidarcies or 2.3×10^{-03} cm/s

Soils in the PVS are characterized as having a low moisture content and a relatively high effective porosity. Soils in the PVS also have a moderate to high permeability to air.

Unsaturated Upper Bellflower Aquitard (45-60 feet bgs)

The unsaturated portion of the UBA occurs from approximately 45 feet bgs to groundwater at approximately 60 feet bgs. Soils within the UBA are characterized as being heterogeneous with varying layers of sands and low permeability silts/clays. The upper 5 to 10 feet of the unsaturated UBA are typically characterized as being a sand layer, while the remaining 5 to 10 feet of the unsaturated UBA are typically characterized as being a silt/clay layer. The average physical properties of unsaturated UBA soils, as measured during the 2003 SVE pilot test from three samples, are summarized as follows (Table 1.1):

Unsaturated UBA, Sand Layer:

- % sand = 81.1%
- % silt/clay = 18.9%
- Dry bulk density = 1.29 g/cc
- Moisture content = 7.1%
- Total porosity = 51.6%
- Effective porosity = 39.9%
- Horizontal permeability to air = 3,458 millidarcies or 3.3×10^{-03} cm/s

Unsaturated UBA, Silt Layer:

- % sand = 23.8%
- % silt/clay = 76.2%
- Dry bulk density = 1.16 g/cc
- Moisture content = 37.2%
- Total porosity = 58.0%
- Effective porosity = 26.4%
- Horizontal permeability to air = 6 millidarcies or 5.5×10^{-06} cm/s

The upper portion of the unsaturated UBA has a high sand content, low moisture content, and exhibits a high effective porosity. The upper portion of the unsaturated UBA exhibits the highest permeability to air in the unsaturated zone. In contrast, the lower portion of the unsaturated UBA has a low sand content, a high moisture content, and a low effective porosity. The lower portion of the UBA exhibits a low horizontal permeability to air.

Saturated Upper Bellflower Aquitard (60-105 feet bgs)

Beneath the Property, the saturated UBA extends from groundwater, at 60 feet bgs, to a depth of approximately 105 feet bgs (**Figure 1.11**). The majority of the DNAPL detected at the Property is found within this lithologic unit as discussed further in Section 2.0. The saturated UBA is heterogeneous and interbedded with layers of fine-grained sand, silty sand, and silt, with lesser amounts of fine to medium sand and occasional clayey intervals. The upper portion of this interval tends to be composed of more sand layers, while the lower portion tends to be composed of more silt layers. These silt zones typically contain minimal sand, are firm to hard, and generally exhibit low or no plasticity. Sand layers within this portion of the UBA are generally well sorted. These interbedded layers vary in both thickness and continuity across the Property. The layers vary in thickness between a minimum of 0.1-foot and a maximum of approximately 4 to 5 feet. Overall, the sediments that comprise the lower portion of the UBA are interbedded, variable in thickness, and display varying degrees of lateral continuity (**Figures 1.11 through 1.13**). Individual intervals, comprised predominantly of either silt or sand beds, often correlate between adjacent borings even though they may vary in overall thickness or the number of beds comprising the interval.

The lowest portion of the UBA from about 95 feet bgs to the base of the unit at about 105 feet bgs consists primarily of silty sand (**Figure 1.13**). This silty sand interval, which ranges in thickness from about 8 to 23 feet, represents a transition from the overlying finer-grained silts to the underlying coarser-grained BFS.

In 2008, the physical properties of saturated UBA soils were measured during 2-dimensional thermal remediation bench-scale testing conducted southwest of the CPA from boring 2DSB-1 (**Figure 1.14**), and the average properties from nine samples (six sand, three silt; Table 1.2) were reported as follows (Earth Tech, 2008b):

Saturated UBA, Sand Layers:

- % sand = 89.4%
- % silt/clay = 10.6%
- Dry bulk density = 1.54 g/cc
- Wet bulk density = 1.85 g/cc
- Total porosity = 42.4%
- Effective porosity = 29.0%
- Vertical permeability to water = 819 millidarcies or $7.1\text{x}10^{-04}$ cm/s

Saturated UBA, Silt Layers:

- % sand = 24.9%
- % silt/clay = 75.1%
- Dry bulk density = 1.45 g/cc
- Wet bulk density = 1.85 g/cc
- Total porosity = 46.4%
- Effective porosity = 15.3%
- Vertical permeability to water = 16 millidarcies or $1.4\text{x}10^{-05}$ cm/s

There are also some lithologic trends in the UBA that occur from west to east across the Montrose Property that are apparent in cross-section A-A' (**Figure 1.11**). In the western area, the lower portion of the UBA contains a greater percentage of sand intervals, whereas in the eastern area there is a higher percentage of silt and silty sand intervals. There is also a gradual easterly dip of approximately 2 degrees from horizontal to the strata that comprise the lower portion of the UBA. This dip is exhibited both by the top of silt layers and a fossiliferous zone encountered near the base of the UBA at depths of approximately 81 to 86 feet (**Figures 1.11 through 1.13**). If present in sufficient quantities, DNAPL can migrate along the top of dipping low permeability silt layers under gravitational forces in the down-dip direction. A geostatistical evaluation of the silt layers in the UBA indicated that the average down-dip direction was 8 degrees north of east as shown in **Figure 1.15** (H+A, 2008d). The geostatistical evaluation also indicated that the silt layers were not laterally continuous over a distance of more than 50 feet. The significance of this issue is that DNAPL can migrate vertically downward through by stair stepping off of the edge of discontinuous silt layers. When migrating DNAPL intercepts a discontinuity in a silt layer, the DNAPL can migrate down to an underlying layer either under gravity or as a result of a DNAPL remedial action.

Bellflower Sand (105-130 feet bgs)

The Bellflower Sand (BFS) underlies the UBA and occurs from approximately 105 to 130 feet bgs. The BFS comprises an interval of nearly continuous sand that coarsens with depth. The upper half of the unit typically consists of fine sand while the lower portion typically consists of fine to medium or fine- to coarse-grained sand. No DNAPL has been definitively identified in the BFS, although EPA believes that DNAPL is present in the BFS based on groundwater data collected in 2008 (H+A, 2008b and 2008c; EPA, 2008b). The potential presence of DNAPL in the BFS is further discussed in Section 2.0.

Lower Bellflower Aquitard

The Lower Bellflower Aquitard (LBA) underlies the BFS and occurs to a depth of approximately 140 feet bgs. The LBA consists predominantly of brown silt, clayey silt, and silty sand.

Gage Aquifer /Unnamed Aquitard

The Gage aquifer, consisting primarily of fine-grained sand, is encountered beneath the LBA to a depth ranging from approximately 200 to 210 feet bgs. An unnamed aquitard underlying the Gage aquifer has been informally named the Gage-Lynwood aquitard. It consists of silt, sandy silt, and/or clayey silt interbedded with fine-grained silty sand and appears to be laterally continuous across the site.

Lynwood Aquifer /Unnamed Aquitard

The upper 20 feet of the Lynwood aquifer consists of dark gray fine- to medium-grained sand. This sand is underlain by as much as 8 feet of dark gray silt or clay of varying plasticity. Approximately 10 to 30 feet of gray, well-graded sand, gravelly sand, and sandy gravel with some silty sand interbeds underlie the top 20 to 30 feet of the Lynwood aquifer. The top of the Lynwood aquifer occurs approximately between 270 to 305 feet bgs across the site. The thickness of the Lynwood aquifer, based on borings drilled at the site, ranges from approximately 33 feet to greater than 108 feet. An unnamed aquitard, approximately 205 feet thick, separates the Lynwood aquifer and the underlying Silverado aquifer beneath and east of the site.

Silverado Aquifer

The Silverado aquifer consists of fine- to coarse-grained, blue-gray sands and gravels with discontinuous layers of silt and clay. The top of the Silverado aquifer was encountered at a depth of 490 feet bgs in the vicinity of the property. The Silverado aquifer reportedly attains a maximum thickness of about 500 feet.

1.5.2 HYDROGEOLOGY

The depth to the water table beneath the property is currently about 60 feet bgs. Historically, the water table has been considerably deeper, potentially on the order of 30 feet deeper than recent water levels, due to over-pumping from the groundwater basin (EPA, 1998). These data indicate that the water table may have been as deep as 90 feet bgs at the Montrose Property in the 1950's. Following adjudication of the groundwater basin in the 1960's, which limited groundwater pumping from the basin and operation of injection barriers along the coast, water levels throughout the basin have been gradually recovering. Groundwater levels may continue to rise in the future which may result in an increase in the saturated thickness of the UBA and a decrease in the portion of the UBA that comprises the unsaturated zone.

Horizontal Gradients

The overall groundwater flow at the Site within the UBA and BFS is primarily horizontal (not vertical). The groundwater flow direction in the UBA in October 2006 was to the south and southeast, but varied locally. Near the Property, the groundwater contours suggest that groundwater in the UBA flows from the northwest and northeast and converges in the area south of the Property. This may be due in part to a pinching out of the fine-grained sediments that comprise the UBA in the area southwest of the Montrose property. The horizontal hydraulic gradient in the UBA immediately downgradient of the Property ranges from 0.0004 to 0.0008 (**Figure 1.16**). The horizontal hydraulic gradient on the Property is somewhat steeper ranging from about 0.001 to 0.002. The regional direction of groundwater flow in the UBA has been about the same since 1988 (H+A, 2007a).

The groundwater flow direction in the BFS in the vicinity of the Site in October 2006 was to the southeast. The horizontal hydraulic gradient in the BFS ranges from approximately 0.0004 to 0.0007 (**Figure 1.17**). The horizontal hydraulic gradient within the BFS beneath the Montrose property is somewhat steeper, averaging about 0.001. The regional direction of groundwater flow in the BFS has been about the same since 1987 (H+A, 2007a).

The groundwater flow direction in the Gage aquifer in October 2006 was to the southeast. The horizontal hydraulic gradient in the Gage aquifer is approximately 0.0007 within the vicinity of the Property. The hydraulic gradient to the southeast of the Property slightly increases to 0.001 (**Figure 1.18**). The regional direction of groundwater flow in the Gage aquifer has been about the same since 1987 (H+A, 2007a).

The groundwater flow direction in the Lynwood aquifer in October 2006 was to the east. The horizontal hydraulic gradient in the Lynwood aquifer is approximately 0.0002 (**Figure 1.19**). The direction of groundwater flow in October 2006 was about the same as the direction of groundwater flow observed in 2002 and 2004 (H+A, 2007a). In 1995, groundwater flow in this unit was to the southeast.

Vertical Gradients

Differences in water level elevations in adjacent hydrostratigraphic units provide an indication of the direction and magnitude of vertical hydraulic gradients across the aquitards that separate these units. The following is a summary of the differences in water level elevation between the UBA, BFS, Gage aquifer, and Lynwood aquifer observed in October 2006.

- UBA - BFS: Water level elevations in the BFS monitor wells were approximately 0.2 to 1.0 foot lower than water level elevations in adjacent UBA monitor wells. This indicates that there is currently a slight downward vertical gradient between the UBA and the BFS. The magnitude of the vertical gradient is greater in the area southeast of the Property and tends to decrease to the west.
- BFS - Gage aquifer: Water level elevations in the Gage aquifer monitor wells were approximately 1.0 foot lower than water level elevations in adjacent BFS monitor wells. This indicates that there is a slight downward vertical gradient between the BFS and the Gage aquifer.
- Gage aquifer - Lynwood aquifer: Water level elevations in the Lynwood aquifer monitor wells were approximately 10 feet lower than water level elevations in adjacent Gage aquifer monitor wells. This indicates that there is a downward vertical gradient between the Gage aquifer and the Lynwood aquifer.

Hydraulic Properties - UBA

Data regarding the transmissivity (T) of the UBA were obtained during DNAPL extraction tests conducted in 1991 and 2004-05 (H+A, 1992; H+A, 2007c). The 1991 extraction test at UBE-1 was conducted at a time when the water table was approximately 6 feet lower than in 2004, when the second extraction test was conducted at this well. The estimated transmissivity obtained from the 1991 test at UBE-1 was approximately 4,500 gallons per day per foot (gpd/ft). When well UBE-1 was tested in 2004, the estimated transmissivity was found to be higher at approximately 5,100 gpd/ft. This apparent increase in T was corroborated by an increase in the specific capacity of well UBE -1. The increase in T appears to be due primarily to the rise in the water table which saturated an additional 6 feet of primarily fine-grained sand.

An additional extraction test was conducted at extraction well UBT-1 in 2004. The T obtained from this test was estimated to be approximately 2,400 gpd/ft. Because the UBA is heterogeneous, the transmissivity determined at each well reflects the arithmetic mean hydraulic conductivity of the sand layers intercepted by the well screen and annular sand pack. The silt layers intercepted by the well screen will contribute significantly less groundwater flow, proportional with the difference in permeabilities between silt and sand layers.

Although extraction tests were also conducted at wells UBE-2 UBE-3, and UBE-4 (**Figure 1.10**), quantitative assessment of the hydraulic properties of the UBA in the vicinity of these wells was not possible. No drawdown data was obtained for these three extraction tests because either there were no monitoring wells within a close enough proximity to the extraction well or because the wells exhibited low sustainable pumping rates that did not generate any drawdown in the monitoring wells. However, based on the lower well yields and the reduced sand layer thickness screened by these wells, the transmissivity of the saturated UBA in the vicinity of wells UBE-2, UBE-3, and UBE-4 is expected to be lower than at UBT-1 and UBE-1.

During the RI, samples were collected from the various hydrogeologic units and laboratory vertical hydraulic conductivity tests were conducted. Although these samples were generally obtained from borings located off-Property, the results give a general sense of the range in the vertical hydraulic conductivity (Kv) for the various soil types that comprise the UBA. Estimated Kv from 14 samples collected from the UBA ranged from a maximum of 8.1 feet per day (2.9 $X10^{-3}$cm/s) to a minimum of 3.2 $X10^{-5}$ feet per day (1.1 X 10^{-8}cm/s). This large range of hydraulic conductivity indicates that the UBA is highly heterogeneous.

<u>Hydraulic Properties - BFS</u>

A 12-hour aquifer test was performed at BFS monitoring well BF-9 during the RI. However, the drawdown data obtained from this test were superseded by results from longer-term testing at pilot test wells installed at the site. Results from the pilot testing program were simulated using the Remedial Design model as part of the design of the groundwater remedy for the Montrose site. Based on the model calibration simulations, the large-scale average hydraulic conductivity for the BFS in the vicinity of the CPA is approximately 250 feet per day (8.8 X 10^{-2} cm/s).

1.6 PREVIOUS INVESTIGATIONS

Various investigations have been conducted to characterize the nature and extent of DNAPL at the Property since it was first detected in November 1987. A chronologic summary of major DNAPL and volatile organic compound (VOC) characterization activities conducted at the Property since 1987 is provided below. This summary does not present all DNAPL-related activities due to the extensive characterization conducted at the Site over the past 21 years. A more complete summary of DNAPL-related activities conducted at the Property up to 1998 is provided in the RI Report (EPA, 1998).

<u>1988/1989</u>

- A focused field investigation was conducted to determine the chemical and physical characteristics of DNAPL and the rate of DNAPL accumulation in monitoring well MW-2 (H+A, 1999).
- Detailed lithologic logging and soil, groundwater, and DNAPL sampling and analyses was conducted at and in the vicinity of the CPA to depths of 130 feet bgs (H+A, 2004a).
- Design, construction, and testing of extraction well UBT-1 and observation wells UBT-2 and UBT-3 in the DNAPL-impacted area (H+A, 1999).
- Design, construction, and sampling of BFS monitoring well BF-9 adjacent to monitoring well MW-2 (EPA, 1998).

<u>1991</u>

- Design, construction, and testing of pilot extraction well UBE-1 for 28 days (H+A, 1992).

<u>1998/1999</u>

- Collection and analysis of DNAPL samples for physical properties and chemical composition to support evaluation of DNAPL remedial technologies and process options as part of the DNAPL FS (H+A, 1999).

<u>2003/2004</u>

- Drilled and sampled a total of 60 borings in the vicinity of the CPA as part of the DNAPL Reconnaissance Program to further define the extent and distribution of DNAPL on-Property (H+A, 2004b).
- Conducted short and long-term SVE pilot tests within the CPA and from all three unsaturated zone layers, including the PD, PVS, and UBA (Earth Tech, 2004a).
- Conducted a soil gas survey at the Property at 33 locations from three different depth intervals, including 5, 15, and 35 feet bgs (Earth Tech, 2004c).

<u>2004/2005</u>

- Design, construction, and extraction testing of groundwater/DNAPL at wells UBE-1, UBE-2, UBE-3, UBE-4, and UBT-1 over a 329 day period. (H+A, 2007c and 2008g).
- Drilling and sampling of soil from 152 borings as part of the Supplemental Soil Investigation in support of the Soil program. This work included 10 borings drilled to 90 feet bgs within the saturated UBA and logged for the presence of DNAPL (Earth Tech, 2005 and H+A, 2006a).

<u>2006</u>

- Completed measurements of the boiling point of the DNAPL, as detailed in an August 2006 report (H+A, 2006b).

- Completed measurements of physical properties of the DNAPL at temperatures ranging from 10 to 90 degrees Celsius (°C) and conducted a bench-scale, one-dimensional steam column test as described in the August 2006 report summarizing the results of this work (Davis, 2006).

2007/2008

- Collected depth discrete groundwater samples and soil samples from the BFS to evaluate the possible presence of DNAPL (H+A, 2008b and 2008c).
- Conducted two-dimensional testing to evaluate the mobility of DNAPL under steam flushing and electrical resistance heating, including physical properties testing of saturated UBA soils and DNAPL (Earth Tech, 2007c, 2007e, and 2008a). The steam flushing work is still in progress. A summary of the first steam run has been provided to EPA (University of Toronto, 2009). An additional run is being planned. Once the steam testing is complete a summary report will be prepared and provided to EPA under separate cover.

  However, despite significant efforts, the electrical resistance heating experiments were terminated due to mechanical failure of the test cell under pressure. Physical properties testing of the DNAPL at temperatures between 20°C and 120°C was conducted in December 2008. Additional details regarding the ERH two-dimensional testing was provided to EPA in March 2009 (Queen's University, 2009).
- Conducted computer modeling of hydraulic displacement alternatives for DNAPL as reported to EPA in January and April 2009 (H+A, 2009a and 2009b).
- Evaluated containment zone timeframes for DNAPL remedial alternatives (H+A, 2008e and 2009c). EPA commented on the containment timeframe memorandum in a letter dated December 23, 2008 (EPA, 2008g). A revised technical memorandum has been generated in response to EPA comments. A copy of the revised memo, responses to EPA comments and a copy of the EPA comment letter are provided in **Appendix G**.
- Evaluated candidate focused treatment areas for thermal DNAPL remedial alternatives (Earth Tech, 2008b).
- Installed one additional well, UBE-5, adjacent to soil boring SSB-12 and monitored for passive DNAPL accumulation (Earth Tech, 2008j). A short-term extraction test was conducted at UBE-5 in December 2008. A summary of the extraction test results will be provided to EPA under separate cover.
- Continued to gauge and purge DNAPL, which has passively accumulated, from on-Property wells screened in the saturated UBA on a semi-annual basis; this activity has been on-going in varying frequencies since 1988.
- Montrose is currently preparing detailed responses to a DNAPL remedial technology study conducted by CH2M Hill in November 2007 entitled "*Responses to EPA Focus Questions Pertaining to the Application of Thermal Treatment and Hydraulic Displacement at DNAPL Sites*". Montrose does not concur with the assessment of DNAPL remedial technologies in that study, and preliminary rebuttal discussions are provided for consideration in **Appendix L** of this FS.
- A significant number of DNAPL reference and case study documents were consulted during development of this FS, not all of which are cited in Section 8 of the DNAPL FS. To capture the sum of information considered during evaluation of DNAPL remedial technologies, a compendium of the reference documents has been prepare and is provided in **Appendix M** of this FS.

1.7 TI WAIVER ZONE

This FS evaluates remedial alternatives for DNAPL associated with the Montrose Site. A similar evaluation process was completed for groundwater contamination associated with the Montrose site. Ultimately, EPA issued a Record of Decision (ROD) which "presents the selected remedial action for (1) groundwater contamination, and (2) isolation and containment of non-aqueous phase liquids (NAPL) (EPA, 1999)" The groundwater ROD indicates that although options are being evaluated for removing some of the DNAPL "it will not be practicable to remove enough (virtually all) DNAPL so as to attain drinking water standards in the immediate vicinity of the DNAPL (EPA, 1999)." In light of this, EPA issued a waiver of the requirement to attain cleanup levels to a region of groundwater in the vicinity of the DNAPL.

As it relates to the TI Waiver zone, the groundwater ROD discusses DNAPL associated with the Montrose site and light non-aqueous phase liquid (LNAPL) associated with the Del Amo Superfund Site. Because of overlap between the areas affected by Montrose DNAPL and Del Amo LNAPL, a single TI Waiver zone was established for the Joint Site (**Figure 1.20**). Details regarding the TI Waiver zone are provided in the groundwater ROD (EPA, 1999). The lateral and vertical extents of the TI Waiver zone for the MCB plume associated with the DNAPL at the Montrose site are summarized below.

1.7.1 LATERAL EXTENT

The lateral extent of the TI Waiver Zone was selected to be as small as possible without causing adverse migration due to containment pumping (EPA, 1999). Since the groundwater ROD requires a containment zone downgradient of the DNAPL-impacted area to contain MCB-impacted groundwater, the TI Waiver zone must be sufficiently large to ensure that DNAPL would not be mobilized by containment pumping. Thus, the TI Waiver zone is larger than the known extent of the DNAPL (**Figure 1.20**). All DNAPL remedial alternatives considered by this FS would be conducted within the lateral extents of the TI Waiver Zone. The lateral extent varies depending on the hydrogeologic unit; it is generally most expansive in the shallowest unit, the water table zone, and smallest in size in the deepest unit, the Gage aquifer.

1.7.2 VERTICAL EXTENT

As indicated in the GW ROD (EPA, 1999), the TI Waiver zone at the Montrose site includes the UBA, the BFS, and the Gage aquifer (**Figure 1.20**). All DNAPL-impacted saturated zones occur within the TI Waiver Zone. As with the lateral extent, the vertical extent of the TI Waiver Zone is larger than the known extent of DNAPL.

1.8 INTERRELATIONSHIP OF DNAPL, SOIL, AND GROUNDWATER REMEDIES

The remedies for soil, groundwater, and DNAPL at the Site are interrelated. DNAPL is present in soils beneath the Property and serves as a source of MCB to groundwater. The combined remedies for soil, DNAPL, and groundwater individually and collectively serve to protect human health and the environment. Additionally, the relationship and timing of the remedies must be considered in order to implement them effectively. As such, the evaluations completed as part of this DNAPL FS have been conducted with consideration to the interrelationship between the potential DNAPL, soil, and groundwater remedial programs.

A groundwater pump and treat remedy was selected for the Site in 1999 as specified in the ROD (EPA, 1999). The ROD establishes requirements for groundwater within the area of DNAPL occurrence, and contains provisions for limiting adverse migration of DNAPL during the groundwater remedy. Additionally, the ROD requires provisions for containment of dissolved-phase MCB surrounding DNAPL sources both during and following the groundwater remedy. The pump and treat remedy will include a series of groundwater extraction and injection wells and an on-Property aboveground treatment system located as shown in **Figure 1.21** (Earth Tech, 2008g). The duration of the active extraction pump and treat remedy is expected to be between 35 and 50 years based on the most recent modeling results (EPA, 2008c), while pumping and treatment for containment is expected to last much longer (H+A, 2008e and 2009c; Appendix G).

A soil remedy has not yet been selected for the Site, and candidate soil remedial alternatives are currently being evaluated as part of a revised Soil FS being prepared concurrently by Geosyntec. A prior version of the Soil FS was submitted to EPA in 1999 (Earth Tech, 1999b) and considered six different remedial alternatives for soil including SVE, capping, and excavation with on-Property treatment. This DNAPL FS evaluates SVE as a remedial technology for VOCs and DNAPL in the unsaturated zone; therefore, the Soil FS will only address VOCs in near surface soils between approximately 0 and 10 feet bgs, while the DNAPL FS will address VOCs in deeper unsaturated zone soils from approximately 10 to 60 feet bgs.

Although remedies for soil and DNAPL have not yet been selected, Montrose conducted a preliminary evaluation of interrelationship issues in 2007 (H+A, 2007b). EPA commented on the Montrose evaluation and conducted its own evaluation (*Interconnections Analysis*, EPA, 2007). Although there were differences in assumptions between the two evaluations, both demonstrated that the interrelationship issues could be reasonably managed so that the various remedies did not significantly interfere with each other.

Because the soil, DNAPL, and groundwater aspects of the site are interrelated, so are the potential remedial programs associated with each are interrelated as well. Therefore, the evaluation of remedial alternatives completed as part of this DNAPL FS was conducted to ensure that the effects on the soil and groundwater programs are fully considered.

1.9 PURPOSE AND ORGANIZATION OF REPORT

The primary objectives of this FS are to develop, screen, and evaluate potential remedial alternatives for DNAPL to the extent necessary to select an appropriate remedy. Data generated during the RI and subsequent DNAPL characterization activities have been used to evaluate remedial options. The FS is a process that includes:

- Identification of Remedial Action Objectives (RAOs) and potential remedial technologies;
- Screening of remedial technologies for their ability to meet requirements of technical feasibility, implementability, and cost-effectiveness requirements;
- Evaluation of whether the assembled screened alternatives can be implemented in a reasonable time frame, and allowing for elimination of less practical alternatives from further evaluation; and
- Completion of the detailed analysis of the retained alternatives with respect to nine established National Oil and Hazardous Substances Contingency Plan (NCP) criteria, which address:
    - Overall protection of human health and the environment;
    - Compliance with applicable or relevant and appropriate requirements (ARARs);
    - Long-term effectiveness and permanence;
    - Short-term effectiveness;
    - Reduction of toxicity, mobility, or volume through treatment;
    - Implementability;
    - Cost effectiveness;
    - Regulatory acceptance;
    - Public acceptance.

The remaining portions of this FS report have been organized into the following sections:

- Section 2.0 – Provides a description of the nature and extent of DNAPL and its constituents in soils underlying the Property.
- Section 3.0 - Describes Remedial Action Objectives (RAOs) and ARARs for DNAPL. General Response Actions (GRAs) for DNAPL are additionally identified for subsequent preliminary screening in Section 4.0.
- Section 4.0 – Provides a description and preliminary screening of the remedial technologies and process options identified as GRAs in Section 3.0.

- Section 5.0 - Provides an assembly of remedial alternatives based on the preliminary screening of remedial technologies and process options conducted in Section 4.0. The assembled remedial alternatives are then initially screened in advance of detailed analysis.
- Section 6.0 - Provides a detailed analysis of the remedial alternatives, retained from the initial screening in Section 5.0, in accordance with NCP criteria (40 CFR 30.430(e)(9)).
- Section 7.0 – Provides a comparative analysis of the remedial alternatives evaluated in Section 6.0.
- Section 8.0 – Provides a list of references used during development of the DNAPL FS.

TABLES

Table 1.1
Physical Properties Analytical Results for the Unsaturated Zone (0 to 60 feet bgs)
Montrose Superfund Site

Lithologic Layer	Sample ID	Depth (ft bgs)	Moisture Content (ASTM D2216) (% wt)	Bulk Density (API RP40) (%)	Total Porosity (API RP40) (%)	Effective Porosity (ASTM D425M) (%)	Vertical Permeability to Air (API RP40) (millidarcy)	Horizontal Permeability to Air (API RP40) (millidarcy)	Atterberg Limits (ASTM D4318)			USCS Classification	Particle Size Summary (ASTM D422/D4464M) (% wt)							
									Liquid Limit	**Plastic Limit**	**Plasticity Index**		**Gravel**	**Coarse Sand**	**Medium Sand**	**Fine Sand**	**Total Sand**	**Silt**	**Clay**	**Silt & Clay**
Playa Deposits	EW-1-10	10	11.7	1.56	42.3	18.9	141	32.6	26.3	14.2	12.1	ML – Sandy Silt	0	0	0.04	34.8	34.9	46.8	18.4	65.1
	EW-1-15	15	23.1	1.45	45.8	13.7	12.7	1.82	28.3	15.8	22.5	ML – Silt with Sand	0	0	0.04	16.6	16.6	54.2	29.2	83.4
	EW-1-20	20	20.4	1.43	47.2	19.2	7.58	1.96	37.5	16.3	21.2	ML - Silt with Sand	0	0	0.01	16.5	16.6	53.4	30.1	83.5
	Average		**18.4**	**1.48**	**45.1**	**17.3**	**53.8**	**12.1**	**Average (%)**				0	0	0.03	22.6	**22.7**	51.4	25.9	**77.3**
Palos Verdes Sand	EW-1-30	30	5.8	1.43	46.3	32.9	1,679	2,168	non-plastic			SP-SM –Poorly Graded Sand with Silt	0	0	0	72.8	72.8	19.5	7.7	27.2
	EW-1-35	35	8.3	1.43	46.1	30.1	1,506	2,341	non-plastic			SP-SM –Poorly Graded Sand with Silt	0	0	0	73.3	73.3	18.0	8.8	26.7
	EW-1-40	40	4.5	1.45	45.3	30.7	3,105	2,803	non-plastic			SM - Silty Sand	0	3.2	32.1	50.4	85.7	(a)	(a)	14.4
	Average		**6.2**	**1.44**	**45.9**	**31.2**	**2,097**	**2,437**	**Average (%)**				0	1.1	10.7	65.5	**77.2**	18.7	8.2	**22.8**
UBA Sand	EW-1-50	50	**7.1**	**1.29**	**51.6**	**39.9**	**2,416**	**3,458**	non-plastic			SM - Silty Sand	0	0	6.35	74.72	**81.1**	15.1	3.8	**18.9**
UBA Silt	EW-1-55	55	41.4	1.07	61.6	17.9	3.66	0.886	66.8	26.8	40	ML – Silt	0	0	0.12	20.10	20.2	63.8	16.0	79.8
	EW-1-60	60	33	1.25	54.4	34.8	8.21	10.4	non-plastic			ML – Sandy Silt	0	0	0.04	27.38	27.4	64.8	7.8	72.6
	Average		**37.2**	**1.16**	**58.0**	**26.4**	**5.9**	**5.6**	**Average (%)**				0	0	0.1	23.7	**23.8**	64.3	11.9	**76.2**

Notes:
Extraction well EW-1 was drilled on June 4, 2003 as part of SVE Pilot Test activities.

(a)	Silt and clay were not differentiated in this mechanically-sieved, coarse-grained sample.
%	Percent
% wt	Percent by weight
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
ft bgs	feet below ground surface
g/cc	grams per cubic centimeter
UBA	Upper Bellflower Aquitard
USCS	Unified Soil Classification System

Table 1.2
Physical Properties Analytical Results for the Saturated UBA (60 to 105 feet bgs)
Montrose Superfund Site

Lithologic Layer	Sample ID	Depth, ft bgs.	Moisture Content, % weight	Dry Bulk Density (API RP40) (g/cc)	Wet Bulk Density (API RP40) (g/cc)	Total Porosity (API RP40) (%)	Effective Porosity (ASTM D425M) (%)	Effective Vertical Permeability to Water (API RP40) (millidarcy)	USCS Classification	Particle Size Distribution, % wt.							Silt & Clay
										Gravel	Coarse Sand	Medium Sand	Fine Sand	Total Sand	Silt	Clay	
Saturated UBA Sand	2DSB-1-65	65	26.2	1.39	1.75	48.25	35.1	1,350	SP	0	0	13.3	77.1	90.4	7.1	2.6	9.6
	2DSB-1-72	72	18.7	1.61	1.91	40.07	27.2	885	SP-SM	0	0	38.0	49.7	87.7	10.1	2.1	12.3
	2DSB-1-75	75	18.9	1.58	1.88	41.22	30.5	1,052	SP	0	0	51.9	44.5	96.4	2.7	0.9	3.6
	2DSB-1-79	79	17.1	1.66	1.95	37.41	26.3	549	SP-SM	2.8	7.0	25.9	53.2	88.9	(2)	(2)	11.1
	2DSB-1-88	88	21.1	1.51	1.82	43.32	25.2	568	SM-Silty Sand	0	0	0	77.7	77.7	15.3	7.0	22.3
	2DSB-1-98	98	19.7	1.50	1.80	43.89	29.6	512	SW	18.3	9.2	6.1	62.0	95.5	(2)	(2)	4.5
	Average		**20.3**	**1.54**	**1.85**	**42.36**	**29.0**	**819**	**Average (%)**	3.5	2.7	22.5	60.7	**89.4**	8.8	3.2	**10.6**
Saturated UBA Silt	2DSB-1-76	76	26.6	1.44	1.83	47.36	32.3	22.1	ML- Silt with Sand	0	0	0	22.7	22.7	66.5	10.8	77.3
	2DSB-1-82	82	35.2	1.32	1.78	51.77	6.2	1.4	ML- Silt	0	0	0	12.6	12.6	67.9	19.5	87.4
	2DSB-1-90	90	19.7	1.60	1.94	40.01	7.4	24.8	ML-Sandy Silt	0	0	0	39.3	39.3	37.5	23.1	60.7
	Average		**27.2**	**1.45**	**1.85**	**46.38**	**15.3**	**16.1**	**Average (%)**	0	0	0	47.1	**24.9**	67.9	19.5	**75.1**

Notes:
Soil samples from boring 2DSB-1 were collected on February 27, 2008 as part of the 2-Dimensional Bench Scale Testing.

%	percent
% wt	percent by weight
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
ft bgs	feet below ground surface
g/cc	grams per cubic centimeter
UBA	Upper Bellflower Aquitard
USCS	United Soil Classification System

FIGURES

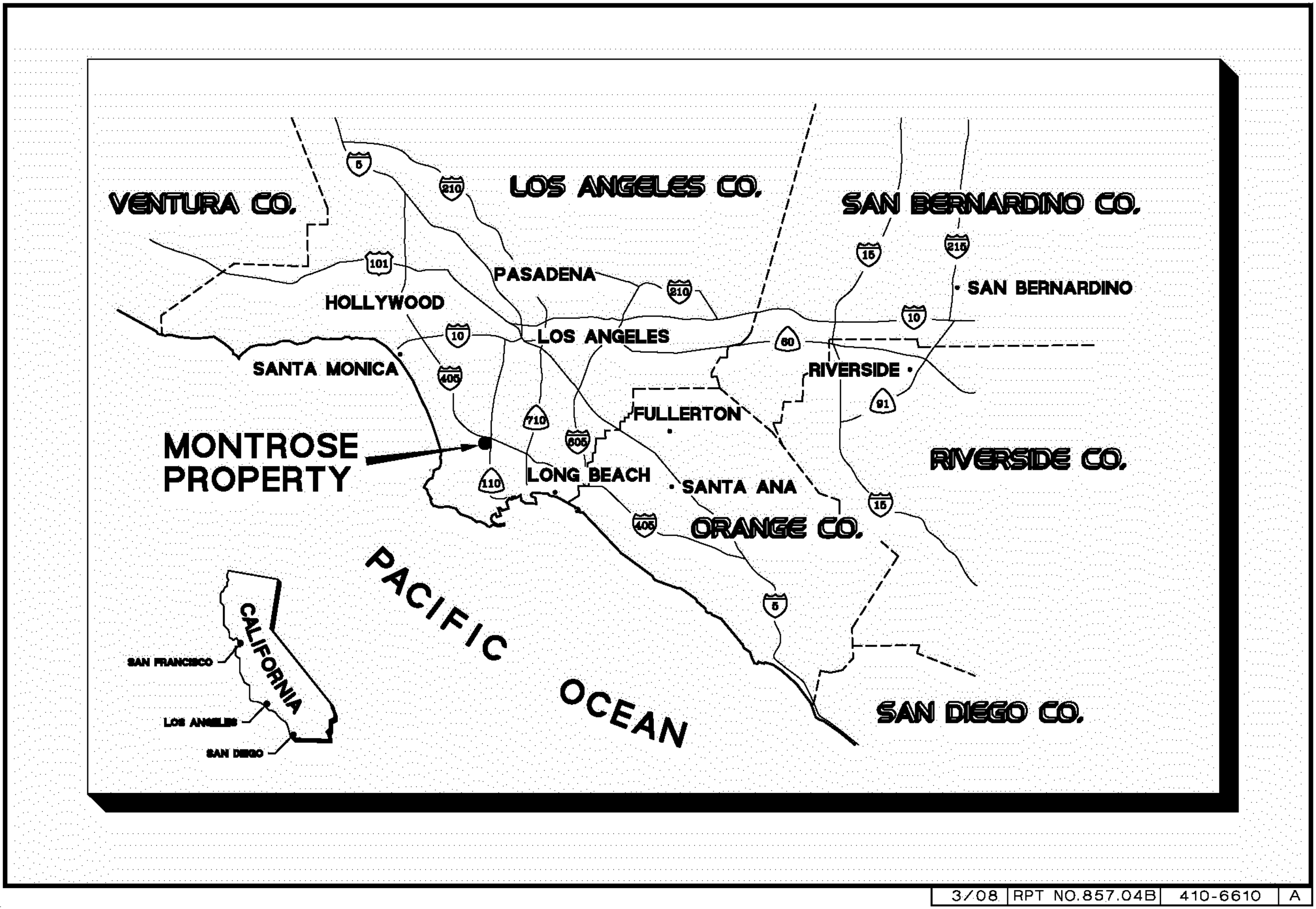
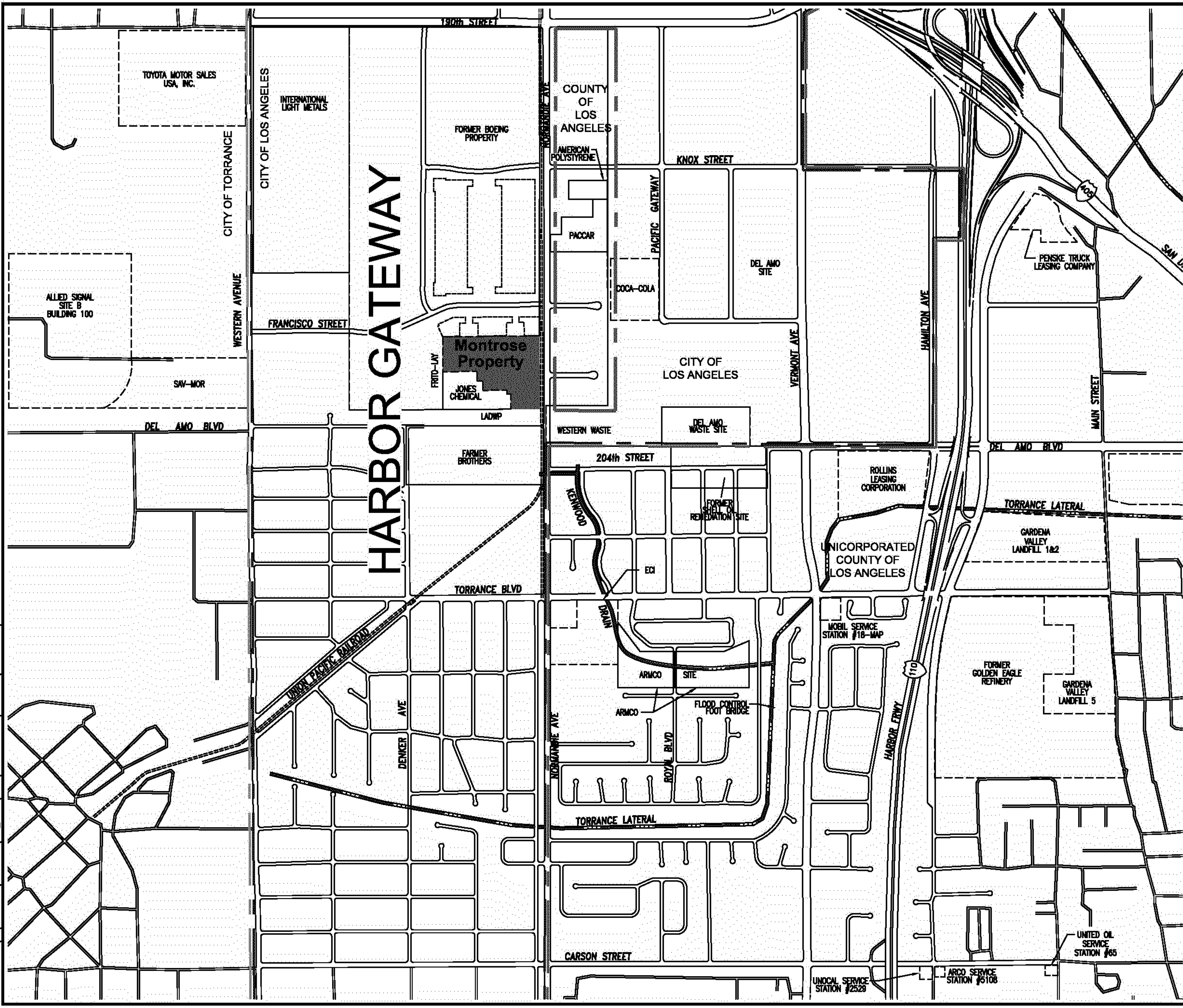


FIGURE 1.1 SITE LOCATION MAP

BOE-C6-0059603



Legend:

- Location of Current Montrose Property Boundary (Surveyed August, 2001)
- City of Torrance from LADPW, 2004
- City of Los Angeles/Harbor Gateway
- Unincorporated Los Angeles County
- Selected Industrial Areas
- Flood Control / Storm Water Channel

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, On-line GIS database, copyright 2006. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors. Montrose Chemical Corp. and Hargis + Associates, map dated September, 2004.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004. TerraServer Georeferenced Imagery, June 2003.
3. Not a Surveyed Map, Site Features, Streets and Boundary locations are approximate.

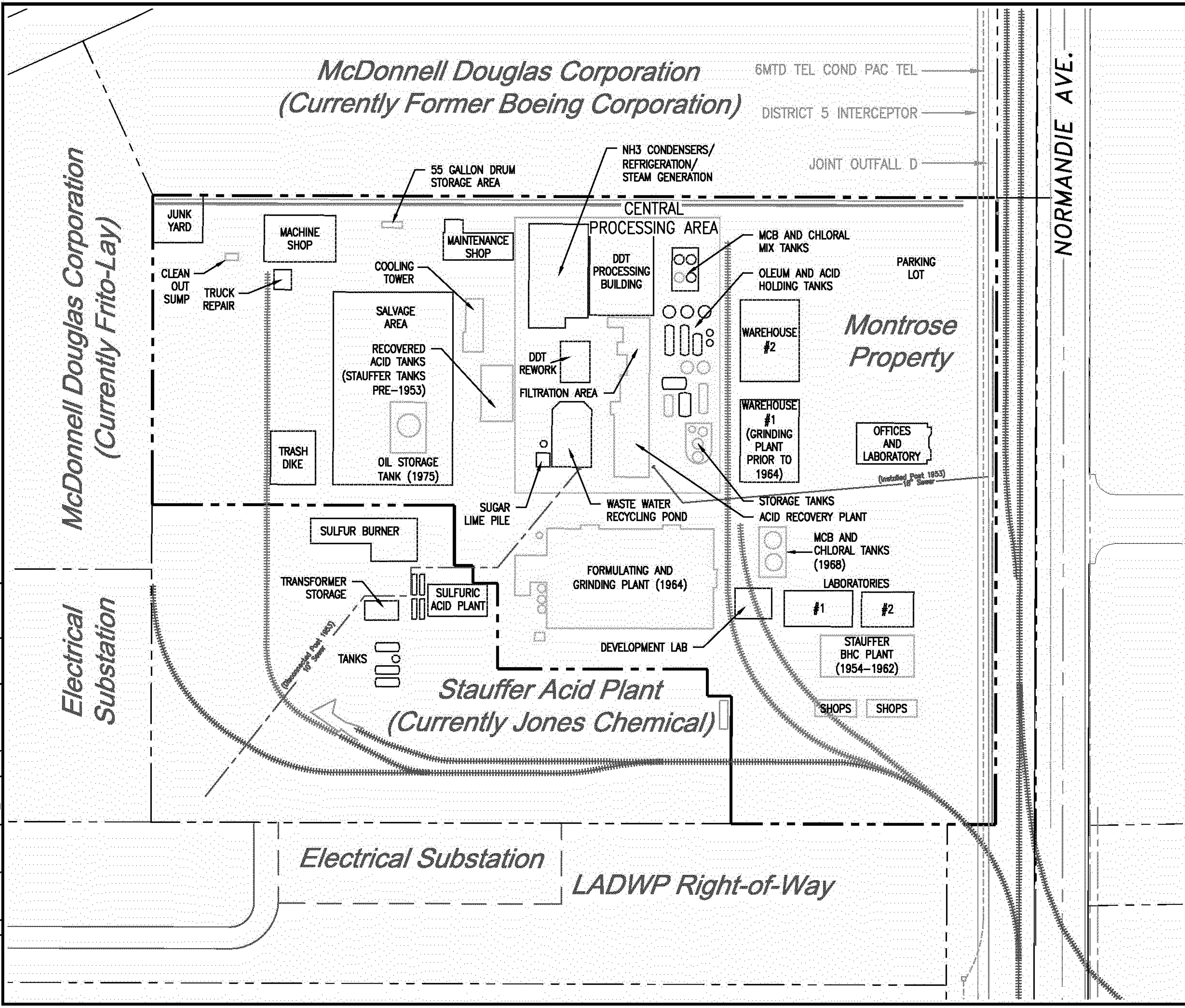
NORTH
0 500 1,000 FEET
SCALE: 1"= 1,000'

Montrose Chemical Corporation

Vicinity Map

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	1.2

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2008\SITEMAPS.0409\DNAPL FS\SECTION 1.0\DNAPL-FS-FIG 1.2-VIN MAP.041709.DWG



FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 1.0\DNAPL-FS-FIG 1.3-HISTORICAL SITE.041709.DWG

Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Railroad Tracks
- Built Post-1953 Building
- Existing in 1953 Building
- *LADWP* Los Angeles Department of Water and Power
- NH3 Ammonia

Note: Not All Historical Features Shown.

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, On-line ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   TerraServer Georeferenced Imagery, 2003.
3. Former Plant Site features based from historic Above Referenced Aerial Photos.
4. Final Remediation Investigation Report EPA Figure 5.20, May 1998.

NORTH

0 60 120 FEET

SCALE: 1"= 120'

Montrose Chemical Corporation

Historical Site Features
(Combined Pre and Post 1953)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	1.3

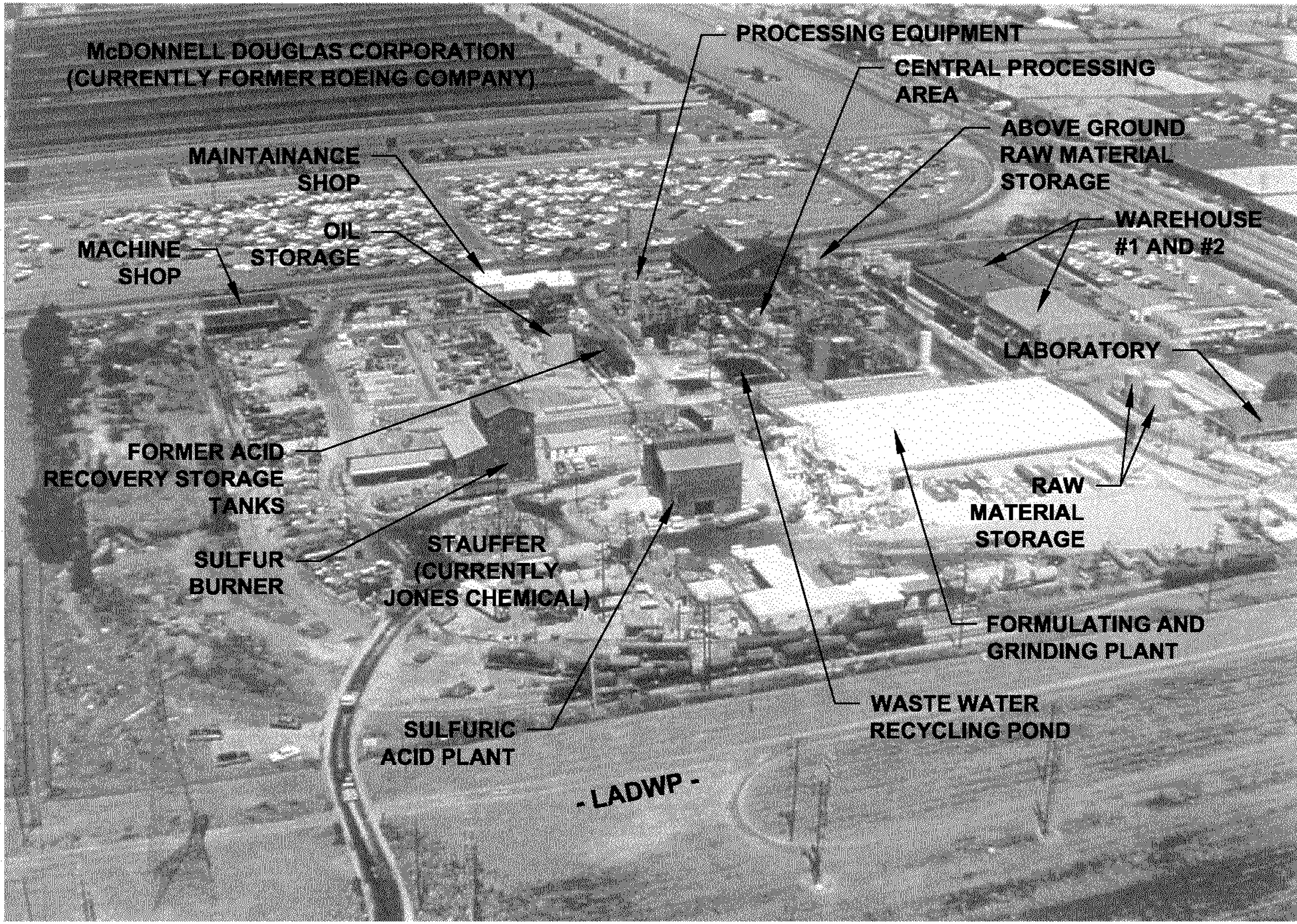
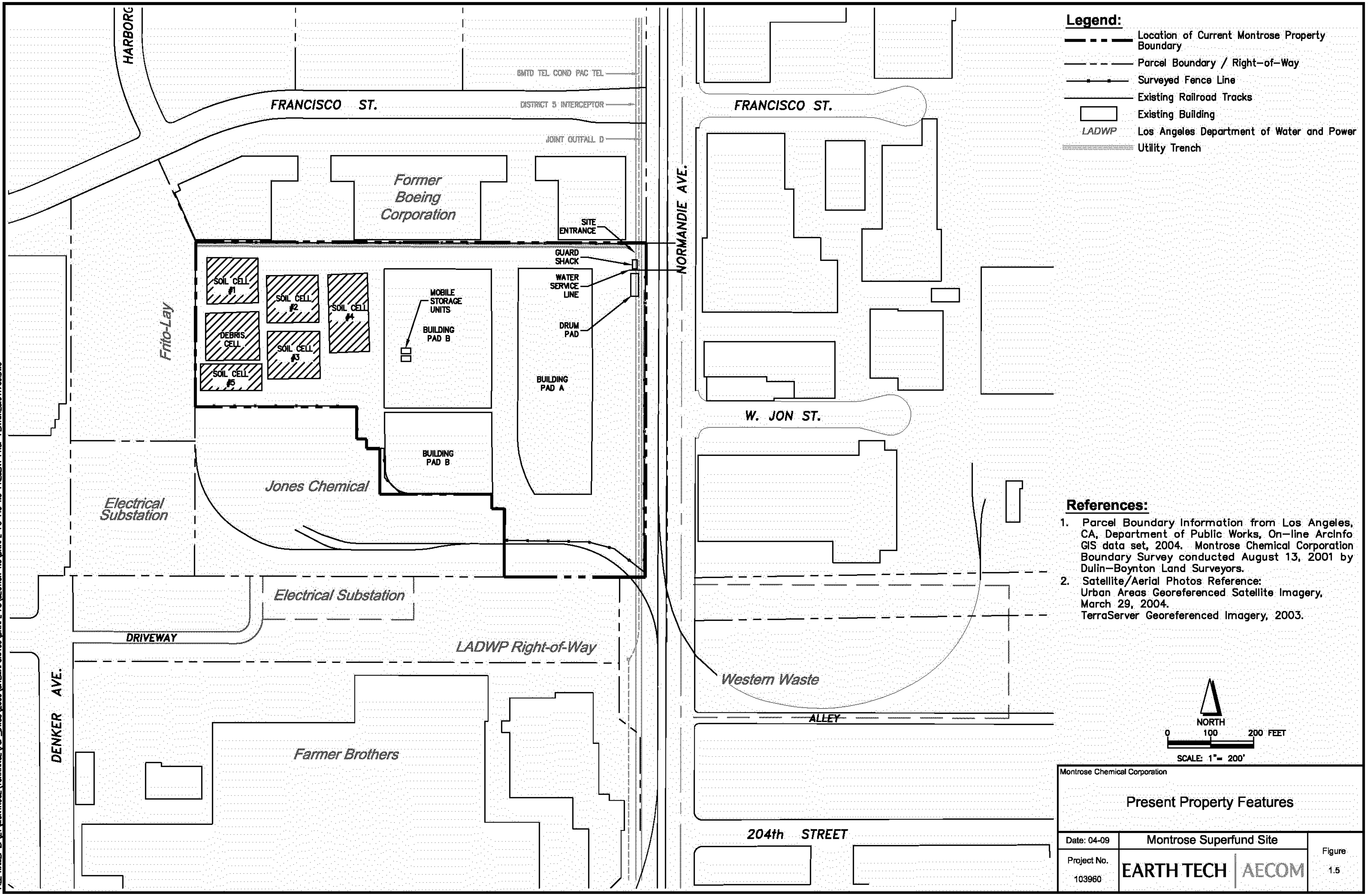
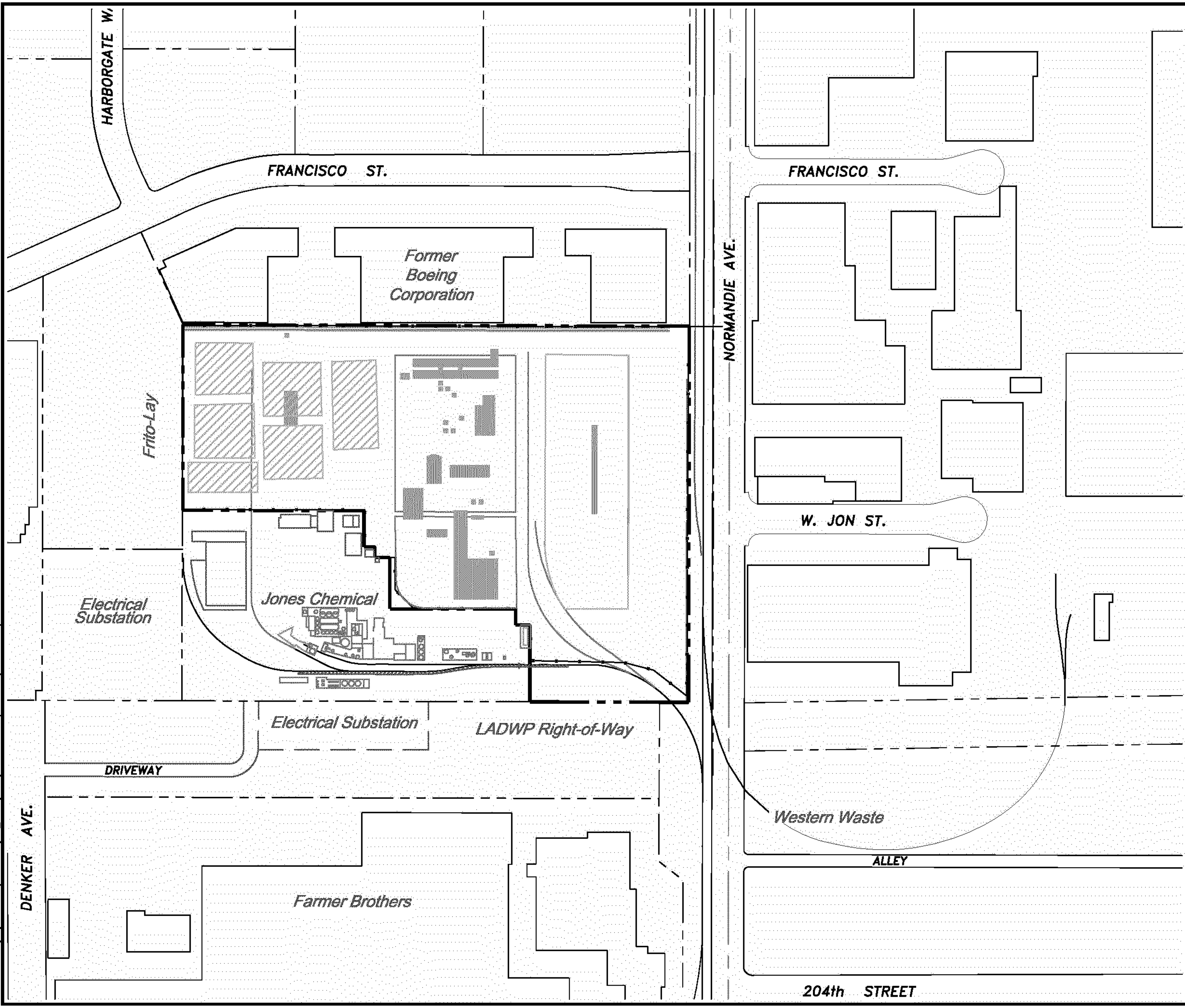


FIGURE 1.4 AERIAL PHOTO, MONTROSE SUPERFUND SITE, MID 1960'S



FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 1.0\DNAPL-FS-FIG 1.5-PRESENT PROP FEATURES.041709.DWG

BOE-C6-0059607



FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 1.0\DNAPL-FS-FIG 1.6-BURIED CONCRETE.041709.DWG

Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Soil Cells
- Raised Buildings Pads
- LADWP — Los Angeles Department of Water and Power
- Concrete Debris Pits and Trenches
- Concrete Slabs and Footings Left in Place

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, On-line ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Former Plant Site features based from historic Above Referenced Aerial Photos.
4. Source: EarthTech, 2003

NORTH

0 100 200 FEET

SCALE: 1"= 200'

Montrose Chemical Corporation

Buried Concrete Debris Locations

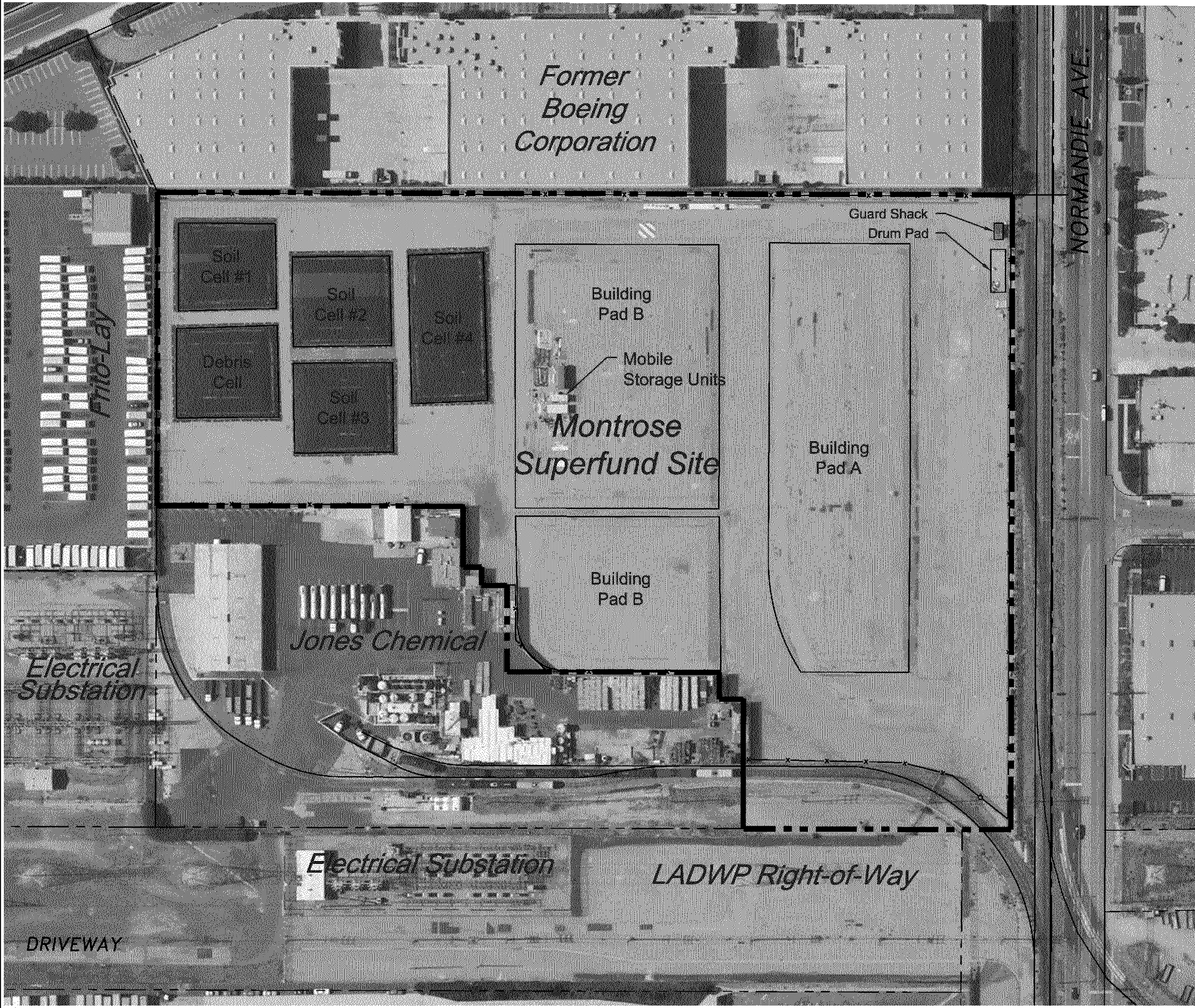
Date: 04-09

Montrose Superfund Site

Project No. 103960

EARTH TECH | AECOM

Figure 1.6



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power

Note:

Not Shown: Soil Cell #5, Installed January 2008

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, On-line GIS data set, Copyright 2006. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.

NORTH

0 60 120 FEET

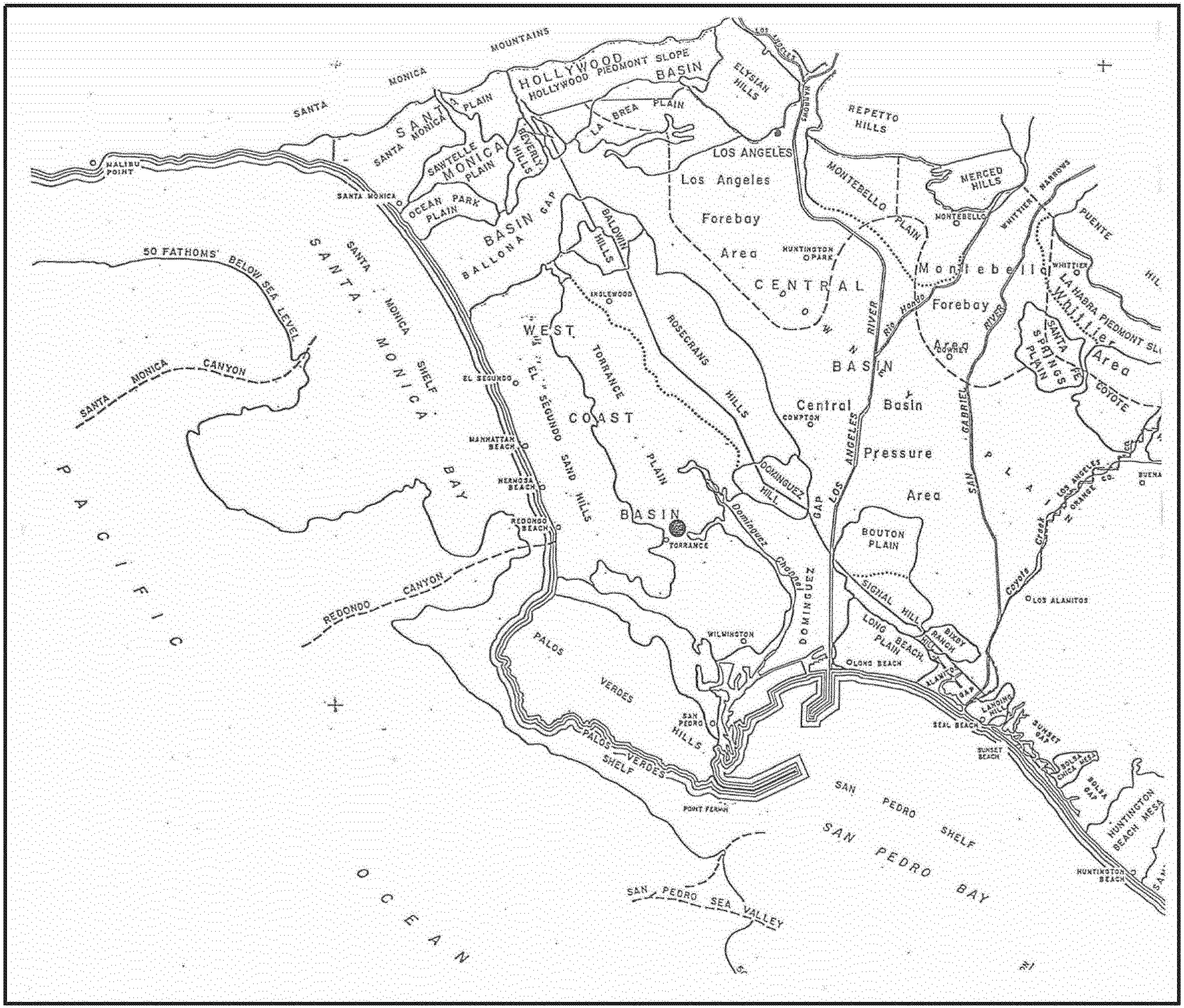
SCALE: 1"= 120'

Montrose Chemical Corporation

Aerial Photo 2007

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH / AECOM	1.7

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 1.0\DNAPL-FS-FIG 1.7-AERIAL PHOTO 2007.041709.DWG



EXPLANATION

MONTROSE PROPERTY

BOUNDARY BETWEEN PHYSIOGRAPHIC FEATURES (DOTTED WHERE APPROXIMATE OR POORLY DEFINED)

BOUNDARY OF GROUNDWATER BASIN

BOUNDARY OF FOREBAY AND WHITTIER AREA

AXIS OF SUBMARINE CANYON

SOURCE: CDWR, 1961

0 4 8
MILES

MONTROSE CHEMICAL CORPORATION
TORRANCE, CALIFORNIA

REGIONAL HYDROGEOLOGIC FEATURES

3/08

FIGURE 1.8

RPT NO. 857.04B | 410-5815 | A

MONTROSE RI (2)					DEL AMO STUDY AREA RI (3)
HYDROGEOLOGIC UNIT		AVERAGE THICKNESS (ft)	BASE ELEV. RANGE (ft/msl)	HYDROSTRATIGRAPHIC UNIT	
UPPER PLEISTOCENE (1) LAKEWOOD FORMATION	UNSATURATED	60 ▼	-12 TO -20	UPPER BELLFLOWER AQUITARD	
	UPPER BELLFLOWER AQUITARD	40	-20 TO -90	MIDDLE BELLFLOWER AQUITARD	B-SAND
					MUD
	BELLFLOWER SAND	45	-70 TO -110		C-SAND
	LOWER BELLFLOWER AQUITARD	30	-85 TO -140	LOWER BELLFLOWER AQUITARD	
	GAGE AQUIFER	60	-155 TO -190	GAGE AQUIFER	
LOWER PLEISTOCENE (1) SAN PEDRO FORMATION	GAGE/ LYNWOOD AQUITARD	20	-170 TO -230	GAGE/ LYNWOOD AQUITARD	
	LYNWOOD AQUIFER	36	-240		
	LYNWOOD SILVERADO AQUITARD	208	-440		
	SILVERADO AQUIFER	>240	NOT REACHED		

EXPLANATION

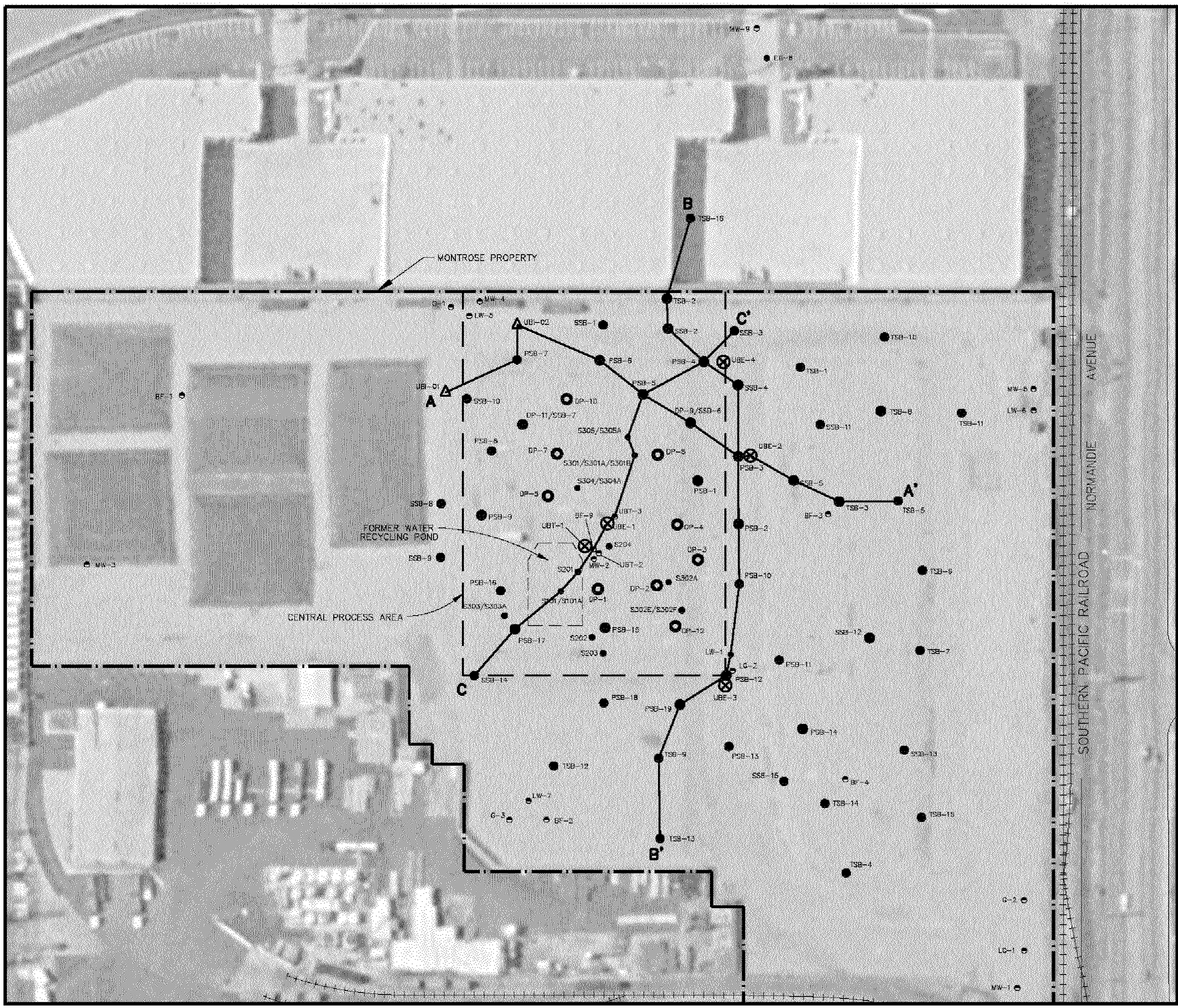
ft = FEET
msl = MEAN SEA LEVEL
▼ = WATER TABLE

SOURCES:

(1) CDWR BULLETIN 104, 1961 AND POLAND ET AL, 1959
(2) ENVIRONMENTAL PROTECTION AGENCY, 1998
(3) DAMES & MOORE, 1998

3/08	RPT NO.857.04B	640-0136	B

FIGURE 1.9 STRATIGRAPHIC COLUMN



EXPLANATION

S305/S305A	SOIL BORING
MW-2	MONITOR WELL
PSB-7	SONIC BORING
DP-10	DIRECT PUSH BORING
UBE-2	EXTRACTION WELL
UBI-01	INJECTION WELL
	PROPERTY BOUNDARY
A——A'	CROSS SECTION LOCATION

SOURCE: HARGIS + ASSOCIATES, 2004b

0 100 200
FEET

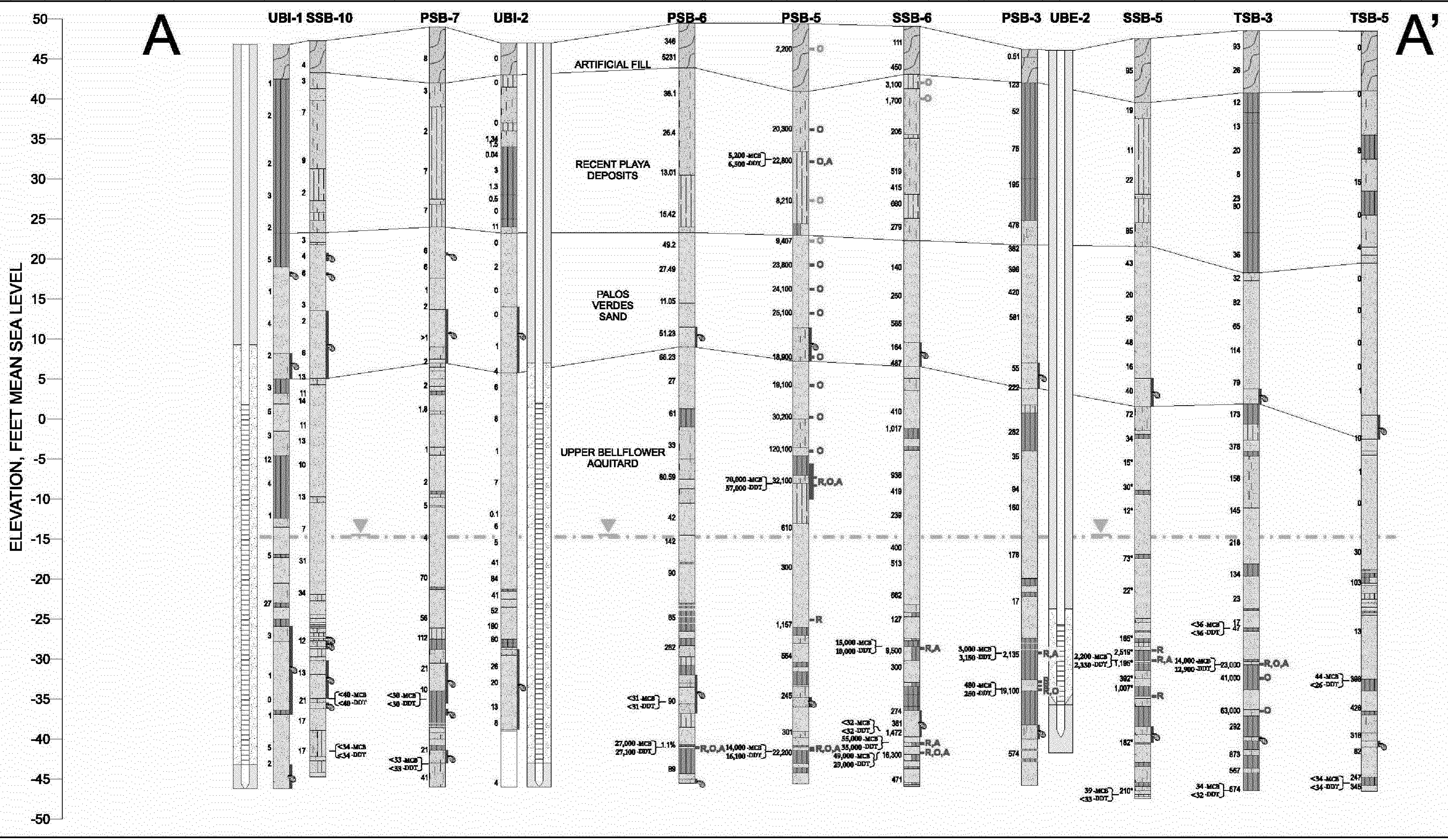
MONTROSE CHEMICAL CORPORATION
OF CALIFORNIA
TORRANCE, CALIFORNIA

CROSS SECTION LOCATION MAP

HARGIS + ASSOCIATES, INC. 3/08

FIGURE 1.10

RPT NO.857.04B | 410-6614 | A



EXPLANATION

FILL
SAND
SILTY SAND
CLAYEY SAND
SANDY SILT
SILT
CLAY
SHELLS

3,146 OVA READING IN PPM

<40 -MCB / <40 -DDT CONCENTRATION OF CHLOROBENZENE AND DDT IN MG/KG

DNAPL PRESENT

DNAPL POSSIBLY PRESENT

V,R,O,A BASIS OF DETERMINATION OF DNAPL PRESENCE
VISUAL
RIBBON TEST
OVA READING
LABORATORY ANALYSIS

APPROXIMATE GROUNDWATER SURFACE (-14.75 FEET MSL) BASED ON JANUARY 2004 MEASUREMENTS

VERTICAL SCALE (feet) 0 5 10

4 TO 1 VERTICAL EXAGGERATION

HORIZONTAL SCALE (feet) 0 20 40

CASING
SEAL
WELL SCREEN
FILTER PACK
SUMP
GROUT BASKET

NOTES

DDT = DICHLORODIPHENYLTRICHLOROETHANE
DNAPL = DENSE NONAQUEOUS PHASE LIQUID
MCB = CHLOROBENZENE
MG/KG = MILLIGRAMS PER KILOGRAM
MSL = MEAN SEA LEVEL
OVA = ORGANIC VAPOR ANALYZER
PPM = PARTS PER MILLION
RIBBON = HYDROPHOBIC DYE-IMPREGNATED FABRIC

SOURCE: HARGIS + ASSOCIATES, 2004b

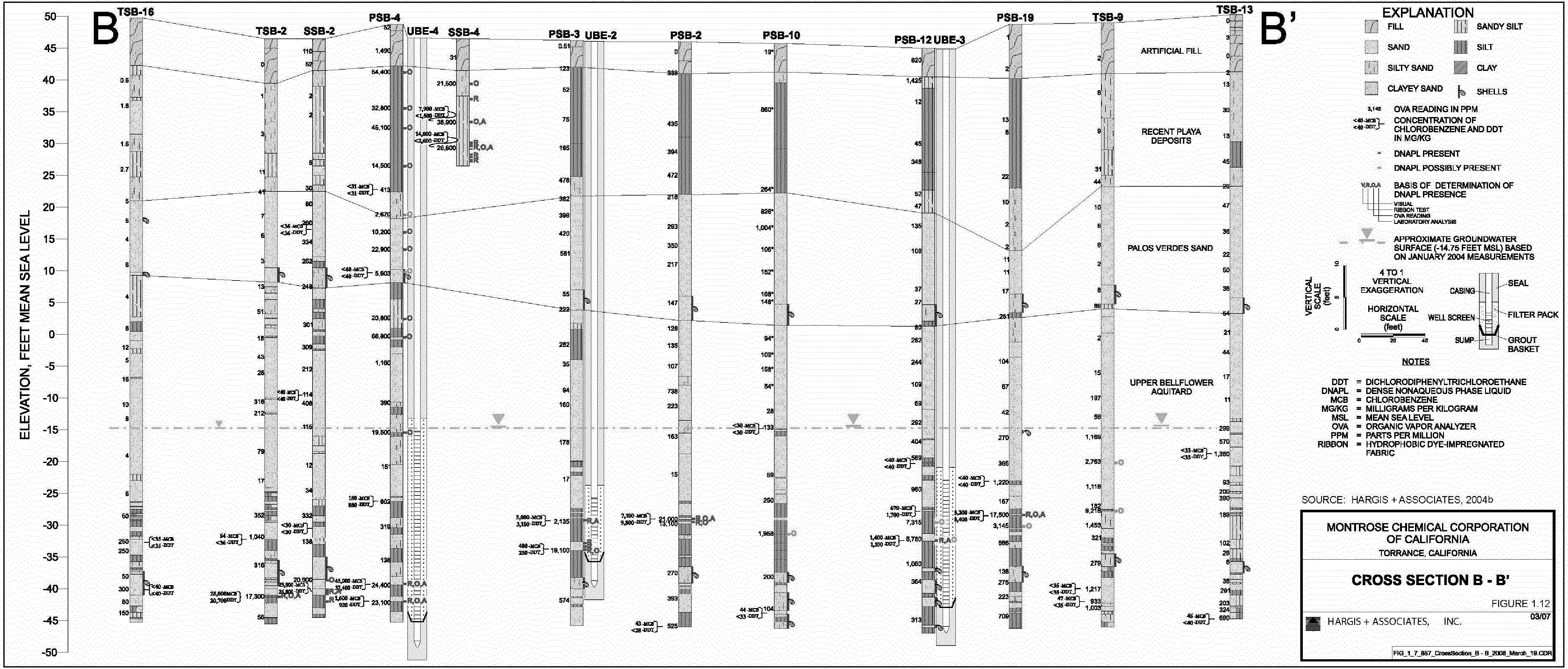
MONTROSE CHEMICAL CORPORATION OF CALIFORNIA
TORRANCE, CALIFORNIA

CROSS SECTION A - A'

FIGURE 1.11

HARGIS + ASSOCIATES, INC. 03/07

FIG_1_6_857_CrossSection_A-A_2008_March_19.CDR



MONTROSE CHEMICAL CORPORATION OF CALIFORNIA

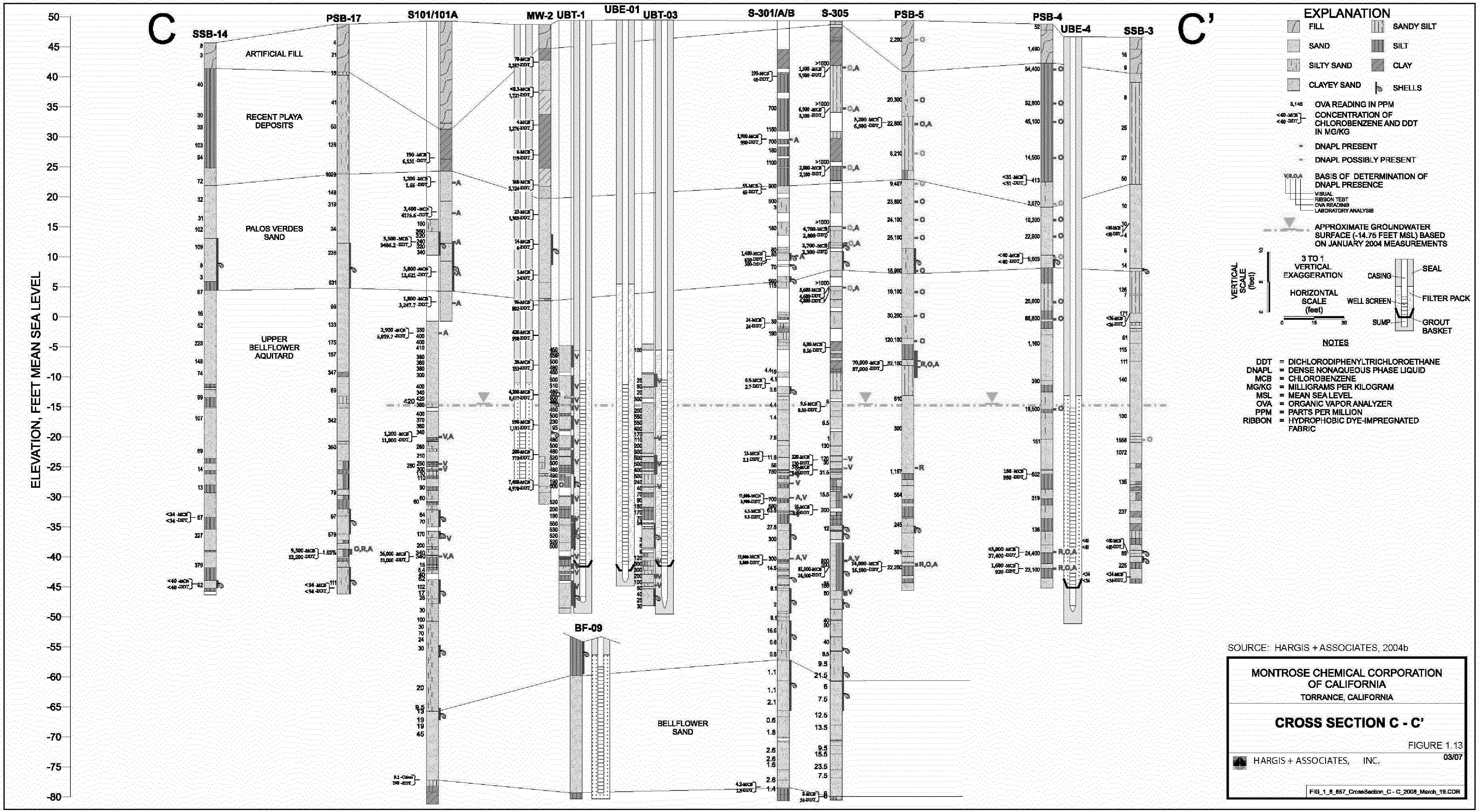
TORRANCE, CALIFORNIA

CROSS SECTION B - B'

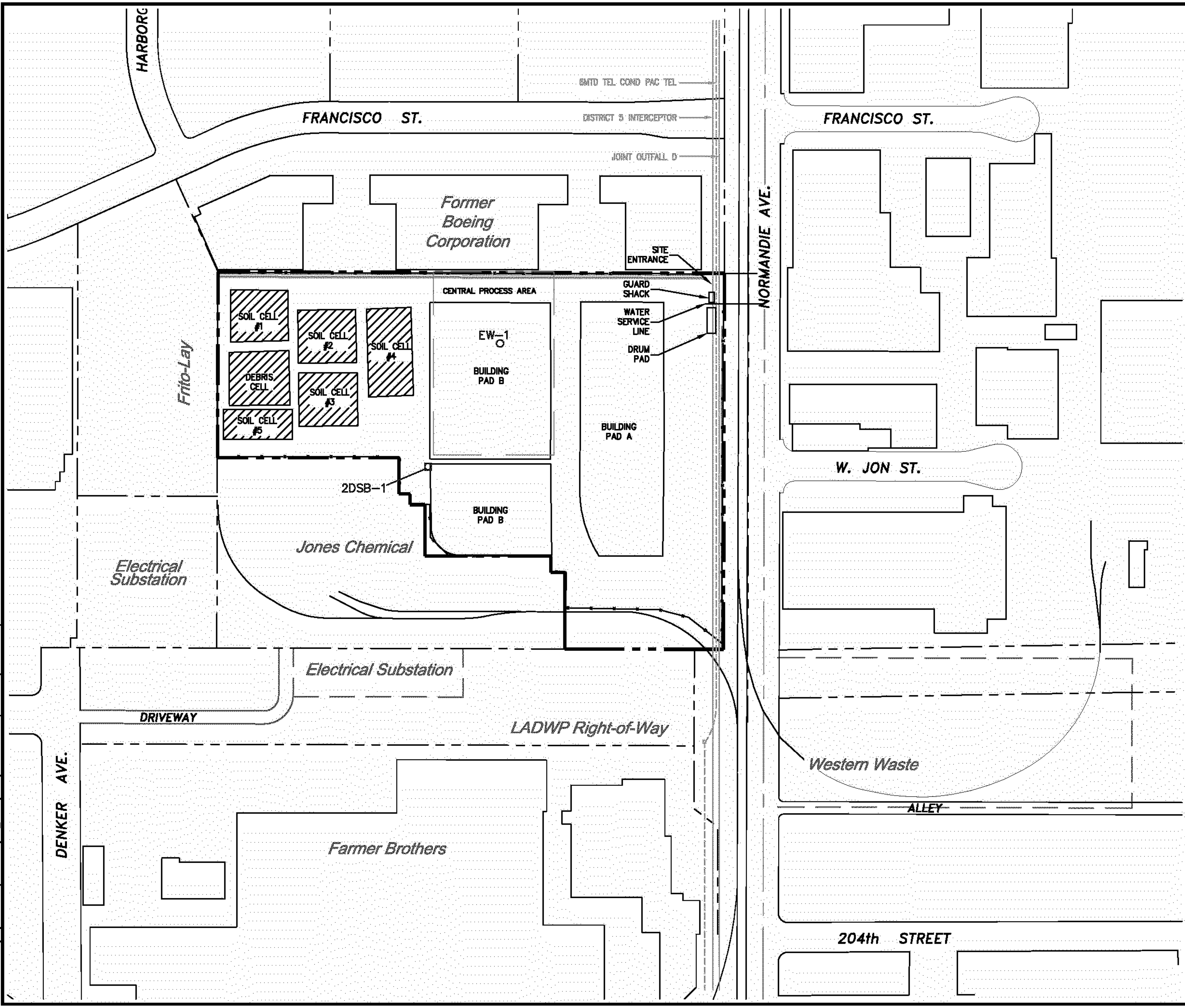
FIGURE 1.12

03/07

BOE-C6-0059614



BOE-C6-0059615



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- Utility Trench
- EW-1 — SVE Pilot Test Extraction Well, Vadose Zone Samples
- 2DSB-1 — 2-Dimensional Bench Scale Test Soil Boring, Saturated Upper Bellflower Aquitard

References:

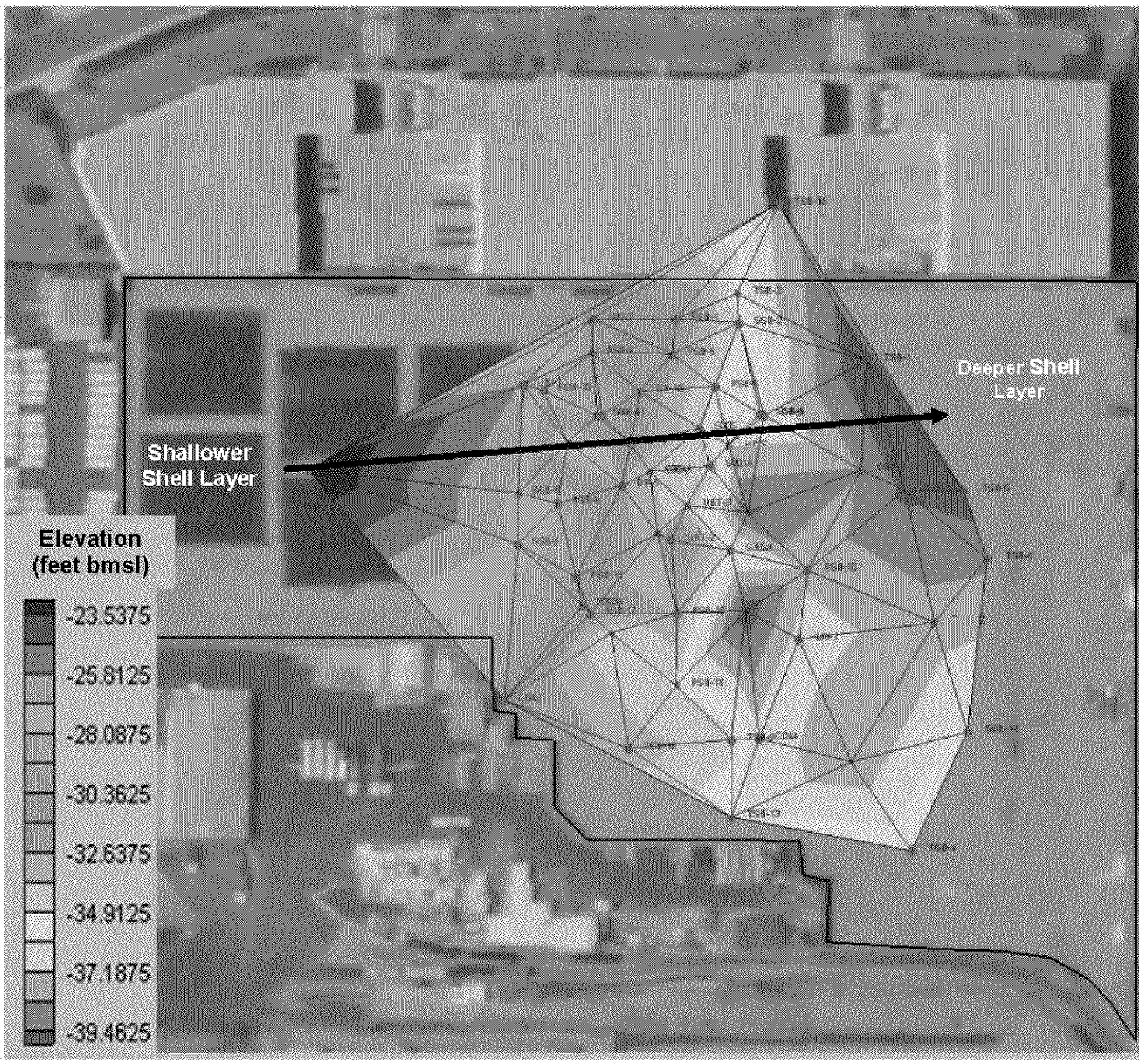
1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, On-line ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004. TerraServer Georeferenced Imagery, 2003.

Montrose Chemical Corporation

Physical Properties
Soil Sampling Locations

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	1.14

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 1.0\DNAPL-FS-FIG 1.14-PHYSICAL PROPERTIES.041709.DWG



SOURCE: HARGIS + ASSOCIATES, 2008d

NOTE:

ARROW DEMONSTRATES GRADUAL DOWN DIP IN UPPER BELLFLOWER AQUITARD, WITH AN AVERAGE DIRECTION 8 DEGREES NORTH OF EAST.

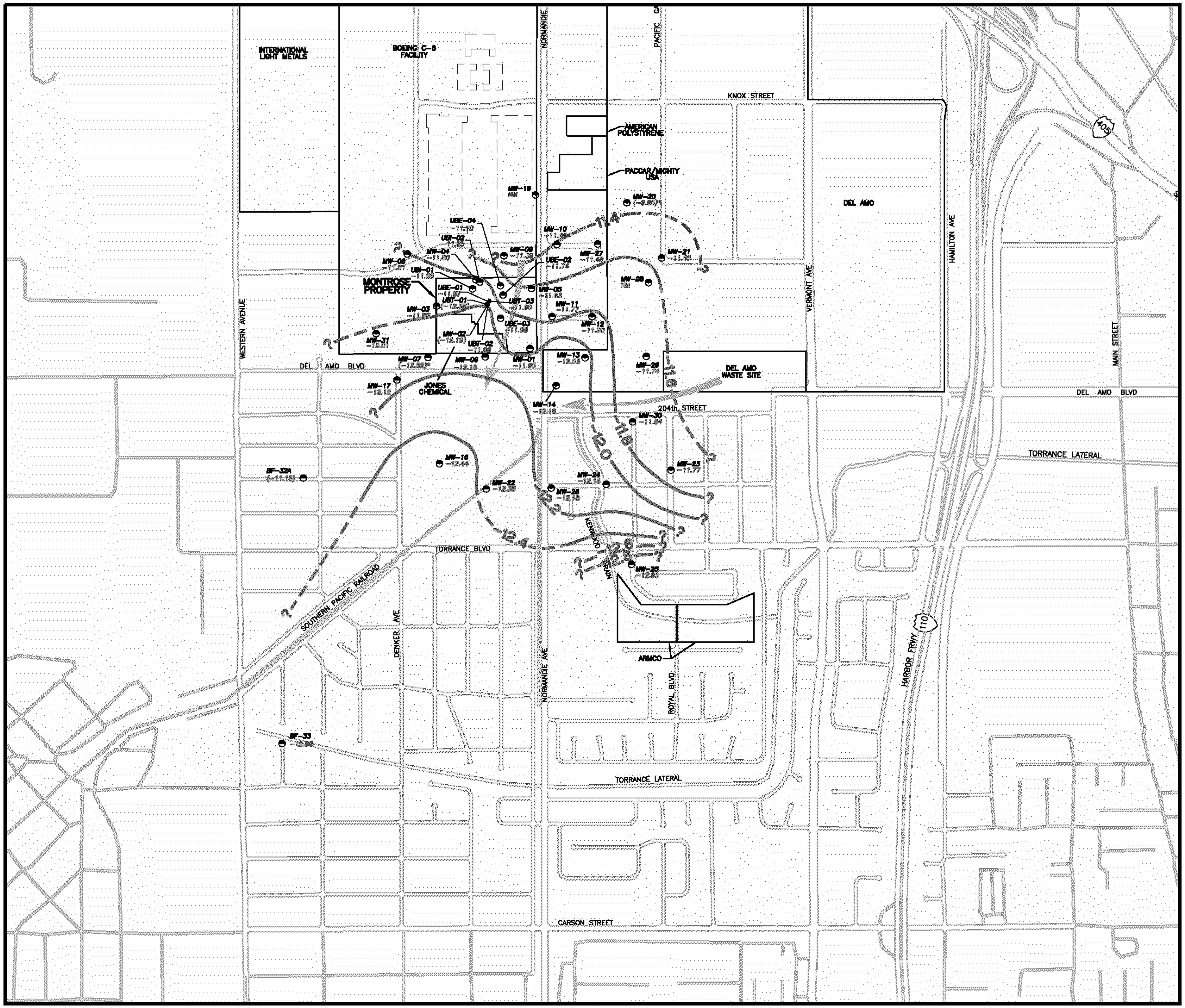
MONTROSE CHEMICAL CORPORATION
TORRANCE, CALIFORNIA

STRATIGRAPHIC BED ORIENTATION SATURATED UPPER BELLFLOWER AQUITARD

HARGIS + ASSOCIATES, INC. 3/08

FIGURE 1.15

RPT. NO.: ______ A



EXPLANATION

MW-31 UPPER BELLFLOWER AQUITARD MONITOR WELL

-12.01 WATER LEVEL ELEVATION FEET MEAN SEA LEVEL

NM NOT MEASURED

( ) NOT CONTOURED

* WATER LEVEL POTENTIALLY EFFECTED BY FLOATING FREE PRODUCT

? —— -12 — — ? CONTOUR LINE OF EQUAL WATER LEVEL ELEVATION IN FEET BELOW MEAN SEA LEVEL; DASHED WHERE APPROXIMATE, QUERIED WHERE INFERRED.

DIRECTION OF GROUNDWATER FLOW

SOURCE: HARGIS + ASSOCIATES, 2007a

0 1,000 2,000
FEET

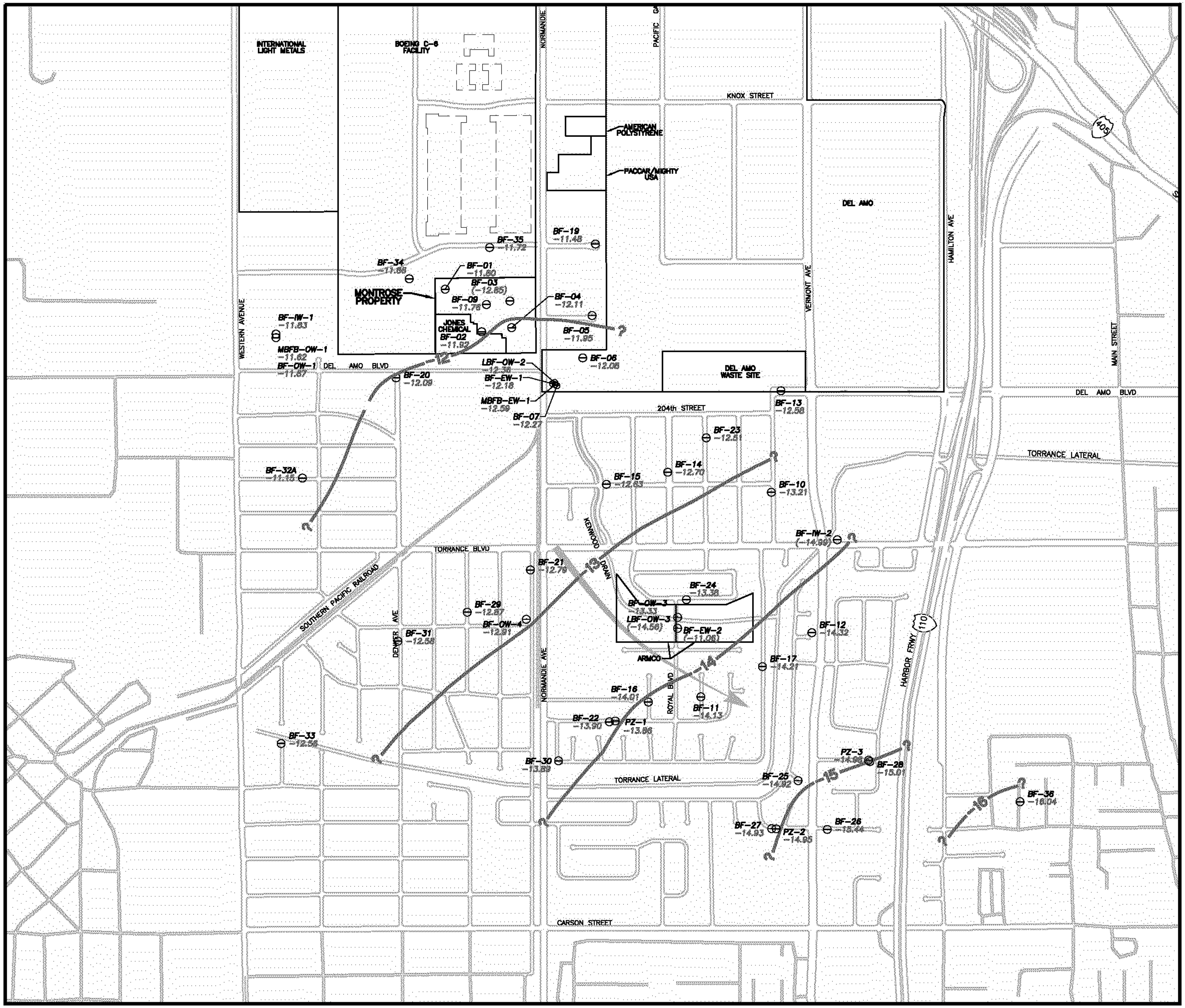
MONTROSE CHEMICAL CORPORATION
TORRANCE, CALIFORNIA

GROUNDWATER ELEVATION MAP
UPPER BELLFLOWER AQUITARD
OCTOBER 2006

HARGIS + ASSOCIATES, INC. 3/08

FIGURE 1.16

RPT NO. 857.04B | 220-1909 | A



EXPLANATION

BF-12 — BELLFLOWER SAND MONITOR WELL

−14.32 — WATER LEVEL ELEVATION FEET MEAN SEA LEVEL

NM — NOT MEASURED

( ) — NOT CONTOURED

? —— −12 — — — ? CONTOUR LINE OF EQUAL WATER LEVEL ELEVATION IN FEET BELOW MEAN SEA LEVEL; DASHED WHERE APPROXIMATE, QUERIED WHERE INFERRED.

DIRECTION OF GROUNDWATER FLOW

SOURCE: HARGIS + ASSOCIATES, 2007a

0 1,000 2,000

FEET

MONTROSE CHEMICAL CORPORATION

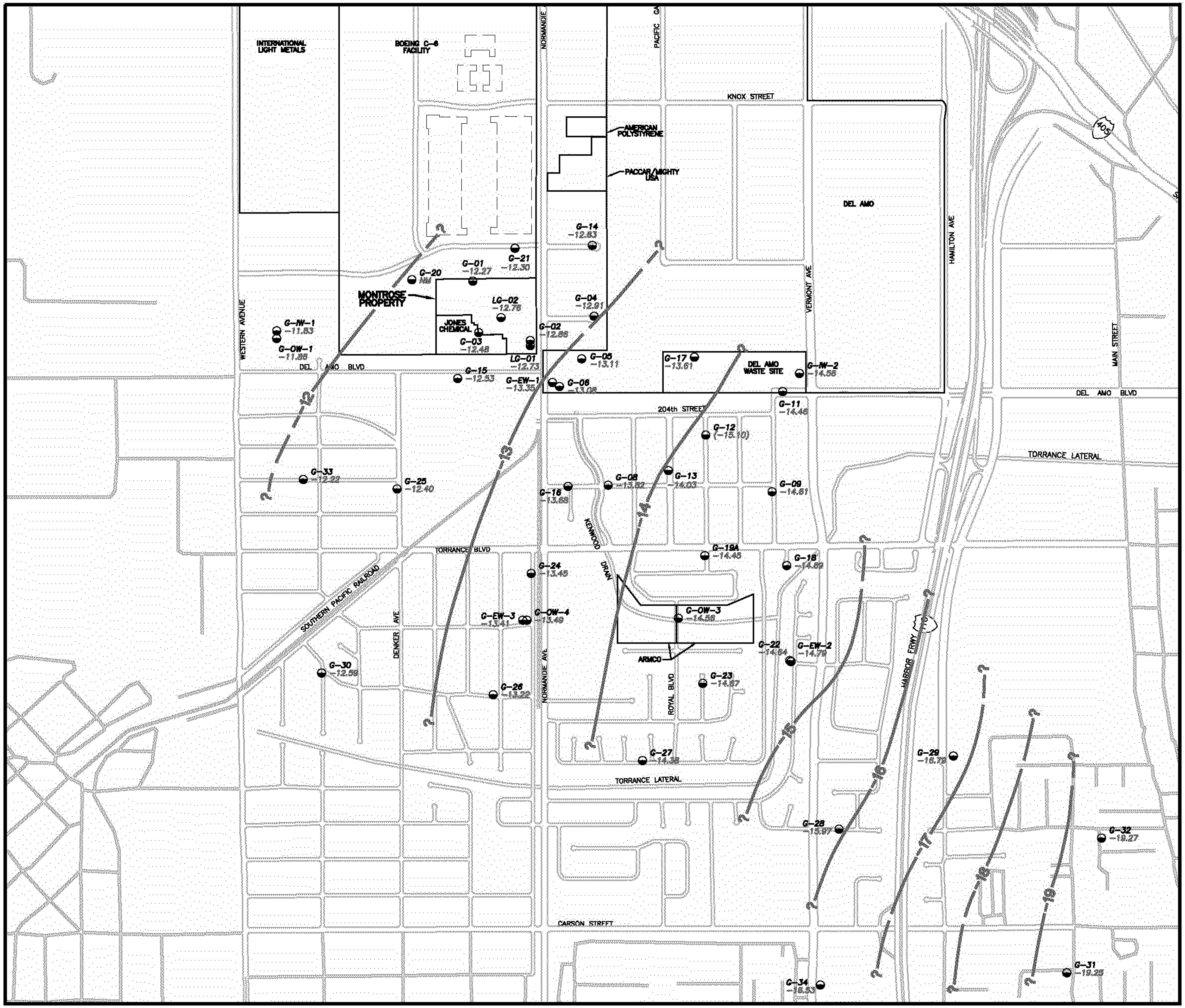
TORRANCE, CALIFORNIA

GROUNDWATER ELEVATION MAP
BELLFLOWER SAND
OCTOBER 2006

HARGIS + ASSOCIATES, INC. 3/08

FIGURE 1.17

RPT NO. 857.04B | 220-1910 | A



EXPLANATION

G-05 GAGE AQUIFER MONITOR WELL

-13.11 WATER LEVEL ELEVATION FEET MEAN SEA LEVEL

NM NOT MEASURED

( ) NOT CONTOURED

? —— -12 — — — ? CONTOUR LINE OF EQUAL WATER LEVEL ELEVATION IN FEET BELOW MEAN SEA LEVEL; DASHED WHERE APPROXIMATE, QUERIED WHERE INFERRED.

DIRECTION OF GROUNDWATER FLOW

SOURCE: HARGIS + ASSOCIATES, 2007a

0 1,000 2,000

FEET

MONTROSE CHEMICAL CORPORATION
TORRANCE, CALIFORNIA

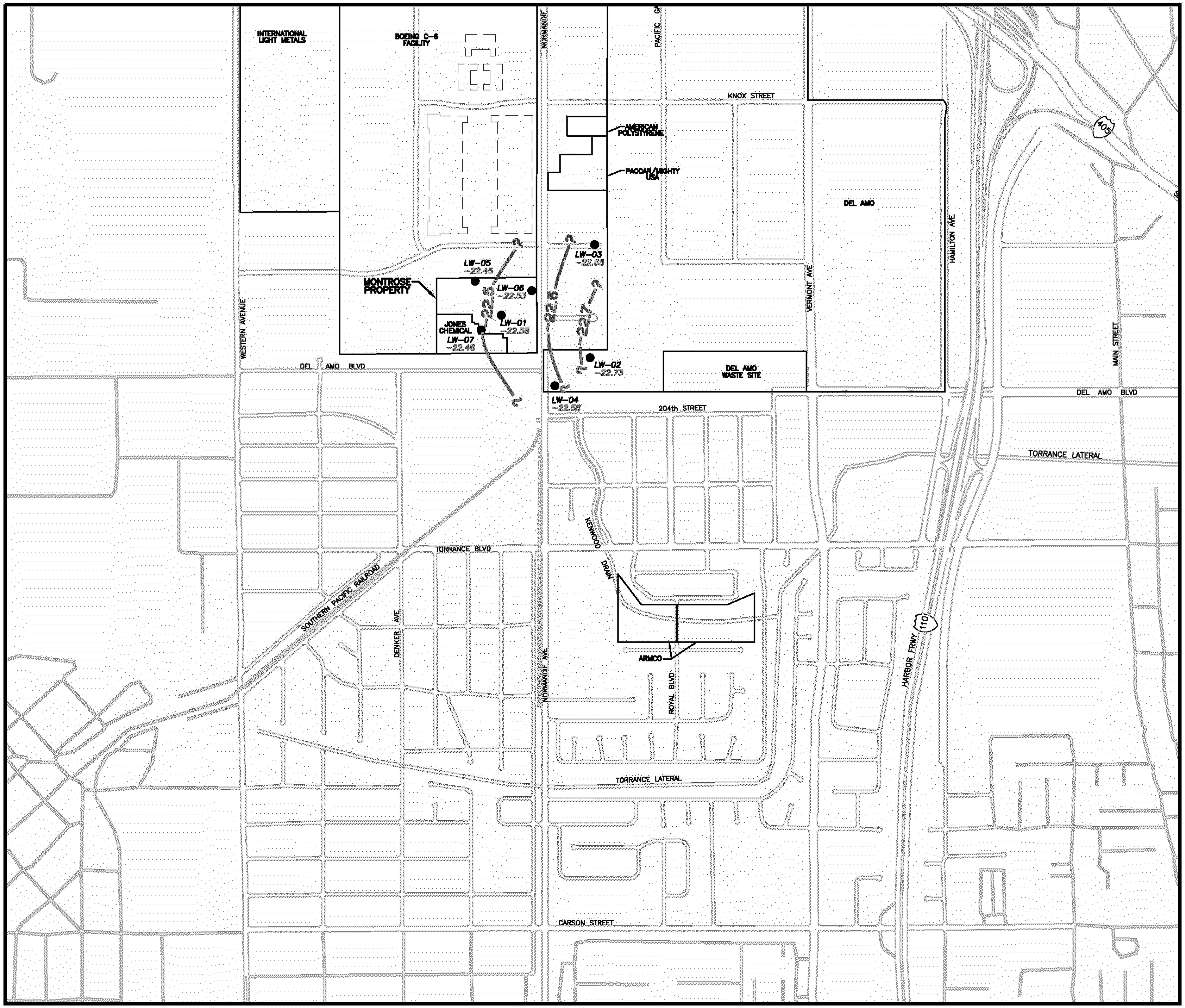
GROUNDWATER ELEVATION MAP
GAGE AQUIFER
OCTOBER 2006

HARGIS + ASSOCIATES, INC. 3/08

FIGURE 1.18

RPT NO. 857.04B | 220-1911 | A

BOE-C6-0059620



EXPLANATION

LW-01 ● LYNWOOD AQUIFER MONITOR WELL

−22.60 WATER LEVEL ELEVATION FEET MEAN SEA LEVEL

( ) NOT CONTOURED

? —— −12 — — ? CONTOUR LINE OF EQUAL WATER LEVEL ELEVATION IN FEET BELOW MEAN SEA LEVEL; DASHED WHERE APPROXIMATE, QUERIED WHERE INFERRED.

DIRECTION OF GROUNDWATER FLOW

SOURCE: HARGIS + ASSOCIATES, 2007a

0 1,000 2,000
FEET

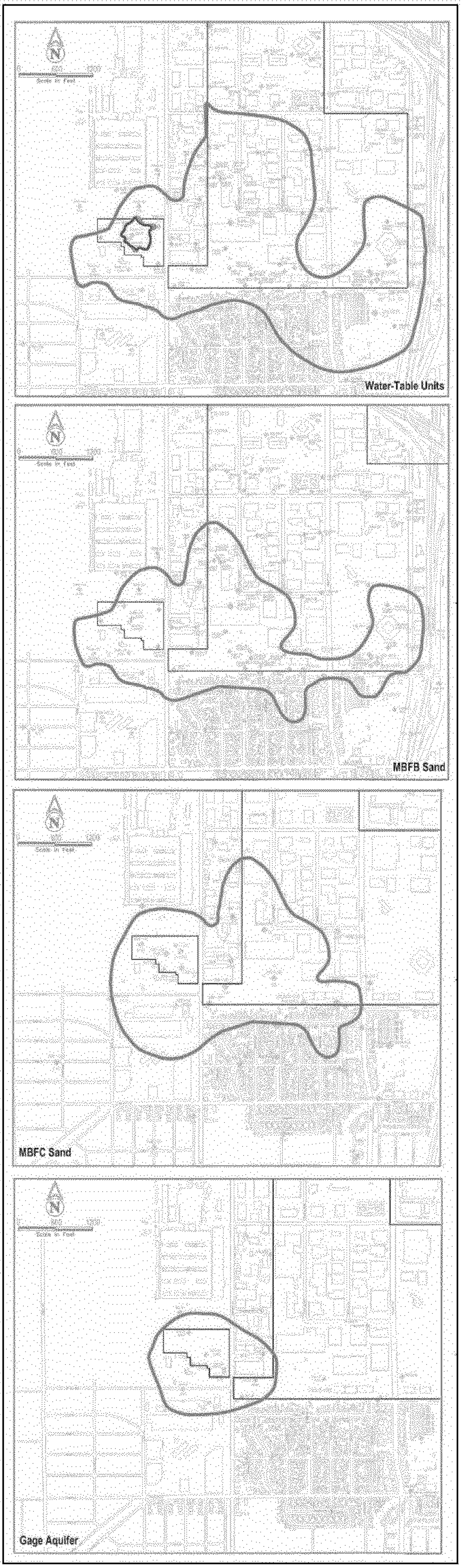
MONTROSE CHEMICAL CORPORATION
TORRANCE, CALIFORNIA

GROUNDWATER ELEVATION MAP
LYNWOOD AQUIFER
OCTOBER 2006

HARGIS + ASSOCIATES, INC. 3/08

FIGURE 1.19

RPT NO. 857.04B | 220-1912 | A



EXPLANATION

MONTROSE PROPERTY

TI WAIVER ZONE EXTENT

EXTENT OF CONFIRMED DNAPL PRESENCE IN THE SATURATED UBA

EXTENT OF POSSIBLE DNAPL PRESENCE IN THE SATURATED UBA

MBFB = MIDDLE BELLFLOWER B-SAND

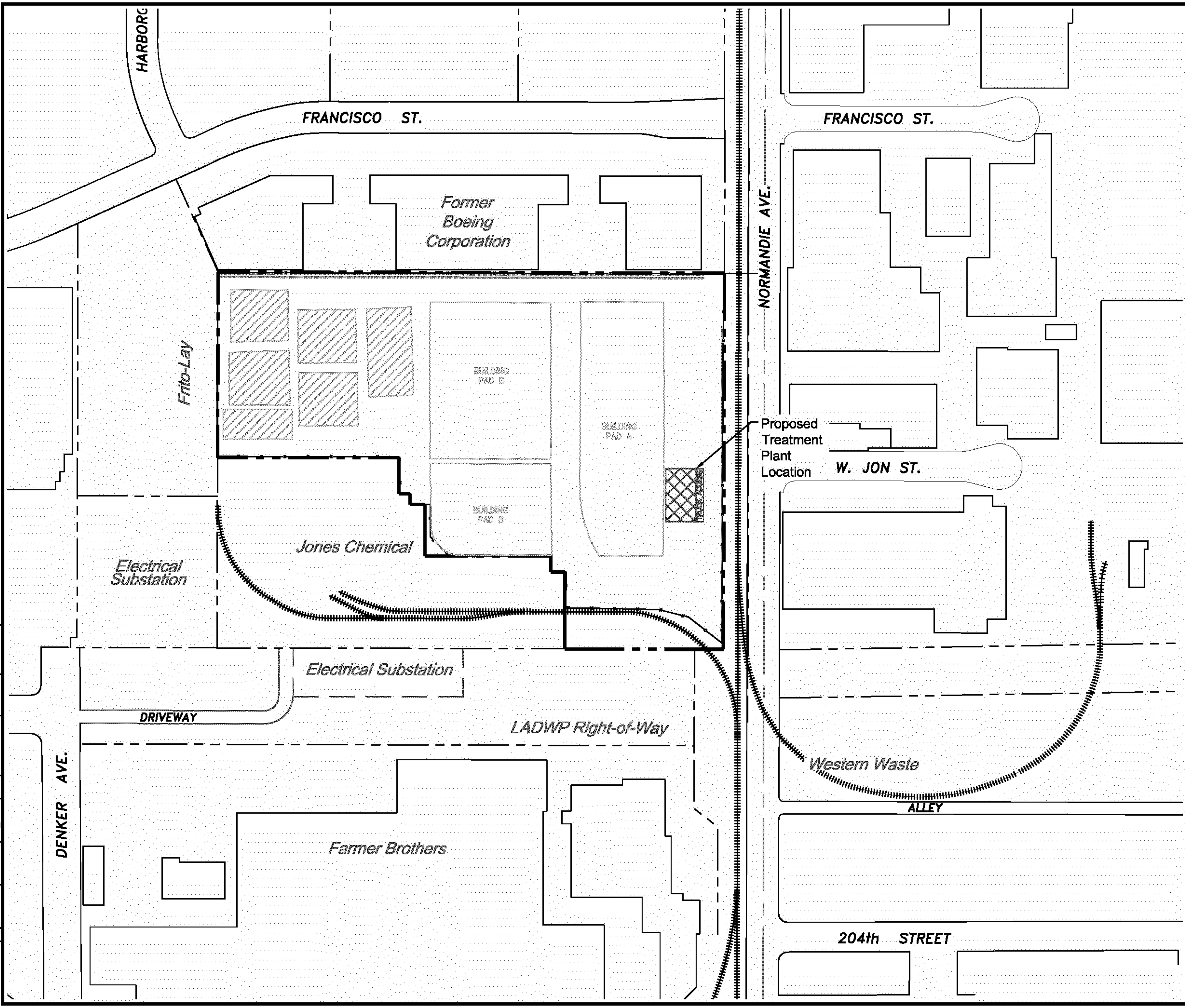
MBFC = MIDDLE BELLFLOWER C-SAND

NOTE:
THE TI WAIVER ZONE IS FOR THE JOINT SITE. THE ROD (EPA, 1999) DOES NOT PROVIDE A PRECISE DEMARCATION BETWEEN THE MONTROSE AND DEL AMO PORTIONS OF THE TI WAIVER ZONE.

SOURCE: ENVIRONMENTAL PROTECTION AGENCY, 1999

3/08	RPT NO. 857.04b	410-6644	A

FIGURE 1.20
TI WAIVER ZONE EXTENT



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- Proposed Treatment Plant
- Temporary Soil & Debris Containment Cells

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, On-line ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Former Plant Site features based on historic Above Referenced Aerial Photos.
4. Source: EarthTech, 2008g

NORTH

0 100 200 FEET

SCALE: 1"= 200'

Montrose Chemical Corporation

Recommended Groundwater Treatment Plant Location

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	1.21

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 1.0\DNAPL-FS-FIG 1.21-TREATMENT PLANT.041709.DWG

BOE-C6-0059623

Section 2.0

Nature and Extent of DNAPL Contamination

2.0 NATURE AND EXTENT OF DNAPL CONTAMINATION

This section presents the nature and extent of DNAPL at the Site as determined by the characterization activities listed in Section 1.6. The extent of DNAPL contamination at the Site is presented for each of the stratigraphic units including the unsaturated zone, saturated UBA, and the BFS. Since the stratigraphic units below the BFS are not related to the occurrence of DNAPL at the Site, they are not discussed in this section. The characterization data presented in this section is organized as follows:

- Section 2.1 – Presents the chemical and physical properties of the DNAPL;
- Section 2.2 – Presents the nature and extent of contamination in the unsaturated zone;
- Section 2.3 – Presents the nature and extent of contamination in the saturated UBA;
- Section 2.4 – Presents the nature and extent of contamination in the BFS;
- Section 2.5 – Presents the extent of DNAPL at the Site;
- Section 2.6 – Presents a summary of DNAPL treatability and modeling studies.

Because the Montrose DNAPL is an unusual mixture, the following sections, besides providing basic information on the character of this material, also provide comparisons of the material to other more common DNAPLs found at other sites.

2.1 NATURE OF DNAPL

Because the Montrose DNAPL is composed of a VOC and a pesticide, the nature of the DNAPL is different from more common DNAPLs such as TCE and PCE. Montrose and EPA conducted independent evaluations of case sites in 2007, between 120 and 177 sites, and only one site was found to contain a VOC/pesticide DNAPL (another MCB/DDT DNAPL): the Arkema, Inc. site in Portland, Oregon. Additionally, there were only four sites where MCB was a component of the DNAPL:

1) the Arkema site;
2) the Silresim site in Lowell, Massachusetts;
3) the GATX Annex Terminal in San Pedro, California; and
4) the Standard Chlorine of Delaware site in New Castle County, Delaware.

Three additional sites were suspected of containing MCB as a minor site contaminant (CH2M Hill, 2007) including: the Loring Quarry site, Hill Air Force Base, and the Eastland Woolen Mill site. However, a detailed review of those sites revealed that MCB was not a contaminant of concern as indicated in Appendix L. Due to the infrequent occurrence of this type of DNAPL, the behavior of this DNAPL under varying conditions is not well documented, and there is an exceptionally limited basis from which to evaluate the success or failure of DNAPL remedial action at sites with these contaminants.

DDT is a solid at standard temperature and pressure, but is highly soluble in MCB. The Montrose DNAPL is saturated with DDT, and any decrease in the percentage of MCB in the DNAPL will result in precipitation of DDT. This effect has been observed at the Property during DNAPL purging, sampling, and extraction testing. DDT readily precipitates out of solution, forming a light-colored precipitate which adheres strongly to solid materials, including Teflon™, and can result in equipment fouling. As further discussed in subsequent sections, several of the remedial technologies and process options considered in this FS have the potential to decrease the MCB fraction of the DNAPL, resulting in DDT precipitation and possible fouling of the aquifer matrix, well screen, pumps, or equipment.

The chemical composition and physical properties of the Montrose DNAPL were evaluated during studies conducted in 1998, 2005, 2006, and 2008. In 1998, a study was conducted to characterize the chemical composition of the DNAPL and to obtain data regarding the physical properties of the DNAPL at standard temperature (20°C) and pressure (1 atmosphere). Non-standard and Site-specific laboratory methods were developed to identify the chemical composition of the Montrose DNAPL (H+A, 1999). Additional studies were conducted in 2005 to evaluate the boiling point of the DNAPL (H+A, 2006b). In 2006, EPA conducted studies of the DNAPL to evaluate density, viscosity, and interfacial tension at varying temperatures up to 90°C (Davis, 2006). Finally, additional testing of the DNAPL composition was conducted in 2008 in coordination with 2-dimensional bench-scale testing.

2.1.1 CHEMICAL COMPOSITION

Five DNAPL samples were collected from individual wells in 1998 and analyzed for chemical composition (H+A, 1999). The DNAPL samples were collected from MW-2, UBT-1 through UBT-3, and UBE-1 (**Figure 2.1**). Results indicated that the DNAPL was composed of approximately 50% MCB by weight (a VOC) and 50% DDT by weight (a non-volatile pesticide). Less than 1% by weight was composed of other VOCs including methyl ethyl ketone (0.5% by weight in one sample), chloroform (0.1 to 0.4% by weight in four samples), 1,4-dichlorobenzene (0.1 to 0.2% by weight in five samples), and pCBSA (0.07 to 0.14% by weight in five samples).

Additional DNAPL samples were collected in 2008 for chemical analysis in advance of 2-dimensional bench-scale testing (Earth Tech, 2007a). Two composite DNAPL samples were collected on March 7, 2008 by combining DNAPL purged from wells UBE-1 and UBE-4. The samples consisted of one primary and one duplicate sample and were analyzed for MCB and Total DDT by EPA Method 8270C modified. Analytical results for both samples were identical, indicating 64% MCB by weight and 36% DDT by weight. No DDD or DDE isomers were detected in the samples. Analytical results of DNAPL samples from 1998 and 2008 are provided in **Appendix A**.

Both results are considered valid and within the range of required analytical precision, since DNAPL from well UBE-4 was not tested in 1998 (the well had not yet been installed). However, the DDT component of the DNAPL has a tendency to precipitate in the sample jar prior to analysis which could result in a reduced concentration of DDT in the DNAPL. Although laboratory procedures established for analysis of the Montrose DNAPL by modified EPA 8270C are intended to minimize the effects of DDT precipitation, Montrose conducted additional analyses of a DNAPL sample from UBE-4 in March 2009 to resolve the DNAPL composition at this well. Results indicated that the DNAPL was composed of 51% MCB and 49% Total DDT by weight (Appendix A), which is consistent with the 1998 results. The 2008 and 2009 DNAPL analytical results will be reported to EPA as part of on-going bench-scale treatability studies, as described in Section 2.6.6. For the purpose of this FS, it is assumed that the Montrose DNAPL is composed of 50% by weight MCB and 50% by weight DDT.

2.1.2 PHYSICAL PROPERTIES

Physical properties of the DNAPL were evaluated during studies conducted in 1998 (H+A, 1999) and 2006 (H+A, 2006b; Davis, 2006). In 1998, the density, viscosity, and interfacial tension of the DNAPL were measured at a temperature of 22 °C. In 2006, boiling point experiments were conducted for both DNAPL and a DNAPL/groundwater mixture. Additionally, EPA conducted experiments in 2006 measuring DNAPL density, viscosity, and interfacial tension at temperatures between 10 and 90°C. The results of the DNAPL physical testing were relatively consistent showing little variability in the physical properties from one well location to another. The results of the physical properties analyses are summarized below:

Physical Properties of Montrose DNAPL

Physical Property	Test Temperature	Result	Year of Test
Density	10 °C	1.228 to 1.239 g/cc	2006 – Davis
	22 °C	1.241 to 1.252 g/cc	1998 – H+A
	90 °C	1.155 to 1.157 g/cc	2006 – Davis
Viscosity	10 °C	3.4 to 3.5 cP	2006 – Davis
	22 °C	2.5 to 2.8 cP	1998 – H+A
	60 °C	1.8 to 2.0 cP	2006 – Davis
Interfacial Tension, DNAPL-Groundwater	10 °C	11.1 to 11.5 dyn/cm	2006 – Davis
	22 °C	13.0 to 15.0 dyn/cm	1998 – H+A
	90 °C	10.6 to 11.8 dyn/cm	2006 – Davis
Boiling Point – DNAPL only[1]	Various	Initial: 128 °C Final: 359 °C	2006 – H+A
Co-Boiling Point – DNAPL/GW mixture[2]	Various	Initial: 96 °C Final: 115 °C	2006 – H+A

1. The boiling point increases as the MCB component of the DNAPL boils off, eventually reaching a maximum temperature when the DNAPL was likely composed solely of DDT.
2. Initially, the DNAPL boiled off more rapidly than the water. After capture of approximately half of the DNAPL, when the MCB component boiled off, the water began to boil off more rapidly than the DNAPL, steadily increasing to a maximum temperature.

g/cc = grams per cubic centimeter
cP = centipoise
dyn/cm = dynes per centimeter

Density

Density is the measure of weight per unit volume for a material and is often compared to water. Contaminants that are immiscible with water and have densities greater than 1.0 g/cc are referred to as DNAPLs. Contaminants that are immiscible with water and have densities less than 1.0 g/cc are referred to as light non-aqueous phase liquids (LNAPLs). The Montrose DNAPL density, 1.25 g/cc at 20°C, is approximately 25% more dense than water. In the saturated zone, the DNAPL will experience a net downward gravitational force, causing it to flow downward through permeable soil layers and to accumulate above low permeability silts or clays (also called capillary barriers).

The Montrose DNAPL density at ambient conditions is considered a moderate density. Compared with other common DNAPLs, the Montrose DNAPL is heavier than creosote (approximately 1.1 g/cc) but is lighter than trichloroethene (TCE; approximately 1.46 g/cc) or tetrachloroethene (PCE; approximately 1.62 g/cc).

Viscosity

Viscosity is a measure of a fluid's resistance to flow. Contaminants with viscosities greater than 1 cP are more viscous than water, while contaminants with viscosities less than 1 cP are less viscous than water. The Montrose DNAPL viscosity, approximately 2.5 cP at 20°C, is therefore 2.5 times more viscous than water. Although the viscosity of MCB (0.8 cP) is less than that of water, the large percentage of DDT in the Montrose DNAPL results in a viscosity well above that of water.

The significance of this physical property is that the flow of Montrose DNAPL through saturated soils will be 2.5 times slower than the flow of water under equivalent hydraulic conditions and saturations. The Montrose DNAPL is considered to have a moderate viscosity in comparison to other common DNAPLs. For example, DNAPLs such as TCE and PCE have viscosities under 1.0 cP, while creosote has a high viscosity of approximately 20 cP (greater than 10 cP in most cases).

Interfacial Tension

Interfacial tension is a measure of the attractive forces at the interface between two immiscible fluids, which, in this case, are DNAPL and groundwater. The interfacial tension results in capillary forces that must be overcome in order to mobilize a fluid through a soil matrix. Low interfacial tensions lead to low capillary forces and indicate that fluids will require less energy to displace from soil pores as compared with high interfacial tensions.

The interfacial tension of the Montrose DNAPL/water of 13 to 15 dyn/cm is low to moderate in comparison with other common DNAPLs. The interfacial tensions of TCE/water, PCE/water, and creosote/water mixtures encountered at sites typically range from approximately 20 to 30 dyn/cm.

Considering all physical properties (i.e., moderate density, moderate viscosity, and low to moderate interfacial tension), the Montrose DNAPL exhibits a moderate mobility as compared with other common DNAPLs.

Boiling Point

The boiling point of a liquid is the temperature at which the vapor pressure above a liquid equals the ambient pressure; at this point a liquid begins to boil. The boiling point of pure MCB at 1 atmosphere is 132°C, which is well above the boiling point of pure water (100°C). However, in the presence of groundwater at atmospheric pressure, the boiling point of an MCB/water mixture is 92°C at 1 atmosphere, which is below the boiling point of pure water and pure MCB. This phenomenon is known as the co-boiling point, where the boiling point at the interface of two fluids is lower than the boiling point of either fluid (i.e. based on Dalton's Law). This principle is fundamental to thermal remediation projects and allows boiling of the DNAPL, at the interface, in advance of groundwater boiling. The co-boiling points for the Montrose DNAPL and other common NAPLs are shown below:

Co-Boiling Point of NAPL/Water Mixtures

NAPL	Co-Boiling Point with Water at 1 atm
Benzene	69°C
TCE	73°C
PCE	88°C
MCB	92°C
Montrose DNAPL	96°C

Notes:
atm = atmosphere

The co-boiling point for the Montrose DNAPL is relatively high compared with other VOCs. For example, saturated soils contaminated with Montrose DNAPL would require an additional 19°C of heating in order to initiate co-boiling as compared to a DNAPL composed of TCE. A comparison of boiling points and vapor pressures (vapor pressure, is the pressure of a vapor in equilibrium with its non-vapor phases) for MCB and other common VOCs is provided below:

Boiling Point and Vapor Pressure of VOCs

VOC	Boiling Point at 1 atm (°C)	Vapor Pressure at 20 °C (mm Hg)	
Benzene	80	81	More Volatile
TCE	87	73	↓
PCE	121	19	
MCB	132	12	Less Volatile

Notes:
mm Hg = millimeters of mercury

Because of the higher boiling point (132°C at 1 atmosphere) and lower vapor pressure (12 mm Hg at 20°C) of MCB, thermal remediation technologies that rely primarily on contaminant volatilization will be less effective for the Montrose DNAPL than for most other VOCs. Creosote is not listed in the above tables because it is not a VOC. Creosote has a high boiling point of approximately 200°C and a low vapor pressure of approximately 0.5 mm Hg at 20°C (Koppers Industries, 2001). Consequently, thermal remediation of creosote DNAPLs rely primarily on displacement mechanisms (i.e., reduction of viscosity) and, to a much lesser extent, volatilization (since temperatures will not be high enough to boil creosote). However, that is not the case for the MCB DNAPL, as volatilization will be key to the success of thermal remediation.

DNAPL-Water Capillary Pressure Curve

DNAPL-water capillary pressure curves provide a measure of DNAPL saturation at varying capillary pressures and provide an indication of DNAPL mobility in the saturated zone. Drainage and imbibition capillary pressure curves for the Montrose DNAPL were measured for a core sample collected from the saturated UBA as part of the 2-dimensional thermal remediation bench-scale testing (Earth Tech, 2008a). DNAPL, soil, and groundwater collected from the Site were used to conduct the capillary pressure measurements.

The capillary pressure measurements were conducted by PTS Laboratories in Santa Fe Springs, California, and a copy of their laboratory report is provided in **Appendix B**. For the drainage curve, DNAPL displaces water in a saturated core at increasing capillary pressures. The drainage curve ended with a maximum DNAPL saturation of 50.7%. For the imbibition curve, water displaces DNAPL at varying capillary pressures, and the curve ended with a minimum DNAPL saturation of 18.9%.

The significance of this value is that the lowest achievable residual DNAPL saturation from this soil type through hydraulic displacement would be 18.9%, provided that the pore space was initially saturated to at least 50.7%. Lower initial DNAPL saturations would lead to lower residual saturations (this is known as the 'initial-residual' relationship). This data point is representative of conditions in this particular soil sample, but residual saturations at the Property will vary with soil conditions. This sample was identified as a fine-grained sand consisting of 89% sand and 11% silt and clay, with an effective porosity of 26% and a vertical permeability to water of 5×10^{-4} cm/s.

While this soil type is reasonably representative of the sand layers within the saturated UBA, soil samples with smaller pore throats, such as present in silts and clays, will generally exhibit higher residual DNAPL saturations.

2.2 SOIL CONTAMINATION IN THE UNSATURATED ZONE

Contamination, sorbed-phase and DNAPL-phase, occurs at the Site in both the unsaturated zone and saturated zone. This section summarizes the occurrence and distribution of contaminants in the unsaturated zone between land surface and groundwater (60 feet bgs). Contamination in shallow unsaturated soils (i.e., surface to approximately 10 feet bgs) is being addressed by the Soil FS, currently under preparation by Geosyntec. Contamination in deeper unsaturated soils (i.e., 10 to 60 feet bgs) is being addressed by this DNAPL FS. The nature and extent of impact to groundwater in the UBA is discussed in Section 2.3, and impact to groundwater in the BFS is discussed in Section 2.4. The nature and extent of DNAPL at the Property is presented in Section 2.5.

Contaminants discussed in this section include MCB and DDT, which are related to the occurrence of DNAPL at the Property, and other VOCs, which can impact DNAPL remedial technologies and process options considered in this FS. Although the unsaturated zone was additionally characterized for metals, concentrations approaching EPA PRGs were infrequently detected and primarily occurred in near-surface soils. Metals in unsaturated soils will not impact DNAPL remedial technologies or process options evaluated in this FS, and therefore, are not presented in this section (but will be addressed in the Soil FS).

The occurrence and distribution of contaminants is based on (i) soil investigation activities conducted during the Remedial Investigation at the Site (EPA, 1998), (ii) a SVE pilot test conducted in 2003 (Earth Tech, 2004a), (iii) a soil gas survey conducted in 2003 (Earth Tech, 2004c), (iv) a DNAPL Reconnaissance Program conducted in 2003/2004 (H+A, 2004b), and (v) supplemental soil investigation activities conducted in 2005 and 2008 (Earth Tech, 2007b).

2.2.1 MCB

MCB is the predominant VOC detected in unsaturated soils at the Property, and the distribution of MCB in the unsaturated zone is shown in **Figure 2.2**. The highest MCB concentration detected at each soil boring is mapped in this figure (i.e. one peak concentration per location). The highest concentrations of MCB, up to 70,000 mg/kg (at boring PSB-5), occur within the CPA. Relatively high MCB concentrations in soil extend from boring S-101 at the former wastewater pond to boring SSB-4 in the northeast corner of the CPA, where raw materials storage tanks were located. DNAPL-impacted soil samples were collected from the unsaturated zone at borings PSB-5 and SSB-4, and MCB was detected in concentrations of 70,000 (at 57.5 feet bgs) and 14,000 mg/kg (at 17 feet bgs) in these two samples respectively. Relatively high MCB concentrations in soil were additionally detected at borings 24D, S302F, and C33 located near the southeastern corner of the CPA. Outside of these source area locations, only low to moderate concentrations of MCB were detected in soil. MCB concentrations in the PD and PVS/unsaturated UBA are mapped in **Figures 2.3a and 2.3b** respectively

MCB in Soil Gas

In 2003, MCB concentrations in soil gas were measured at depths of 5 and 15 feet bgs in the PD and at 35 feet bgs in the PVS, from up to 33 locations (Earth Tech, 2004c). MCB concentrations in soil gas are mapped at each of these depths in **Figures 2.4a through 2.4c** and summarized as follows:

MCB at 5-feet bgs in the PD

- MCB concentrations in soil gas ranged from <0.2 to 98 ppmv.
- The maximum MCB concentration detected in soil gas was 98 ppmv at SG14, located east of the CPA at Building Pad A.

MCB at 15-feet bgs in the PD

- MCB concentrations in soil gas ranged from <0.2 to 955 ppmv.
- The maximum MCB concentration detected in soil gas was 955 ppmv at SG16A, located within the CPA and former water recycling pond.

MCB at 35-feet bgs in the PVS

- MCB concentrations in soil gas ranged from <0.2 to 1,911 ppmv.
- The maximum MCB concentration detected in soil gas was 1,911 ppmv at SG21, located in the southeast corner of the CPA.
- MCB concentrations in soil gas greater than 800 ppmv were observed at SG08, SG16A, SG17, SG21, SG25, and SG29, extending from the CPA over an area extending both east and southeast of the CPA.

2.2.2 ESTIMATED MASS OF MCB IN THE UNSATURATED ZONE

To support evaluation of remedial technologies and process options, the mass of MCB in the unsaturated zone was estimated as shown in **Appendix C**. The average MCB concentration within the impacted areas shown in **Figures 2.3a and 2.3b** were used to estimate the MCB mass. Because soils in the PD exhibit low permeability to air, the mass of MCB was estimated for two depth intervals corresponding to the PD (0-25 feet bgs) and the PVS/unsaturated UBA (25-60 feet bgs) as follows:

- PD (0 to 25 feet bgs): An estimated 237,000 pounds of MCB are present, including DNAPL-phase MCB detected at 17 feet bgs in SSB-4.
- PVS/unsaturated UBA (25 to 60 feet bgs): An estimated 261,000 pounds of MCB are present, including DNAPL-phase MCB detected at 57.5 feet bgs in PSB-5.

Other VOCs occur in unsaturated soils in substantially lower concentrations and frequencies. Those VOCs are not components of DNAPL, they do not significantly contribute to the mass of VOCs at the Site, and they will not significantly impact remedial alternative analysis or containment timeframes. For these reasons, the mass of VOCs other than MCB are not presented in this FS. Although DNAPL-phase DDT in the saturated zone is considered by this FS (as presented in Section 2.5.5), sorbed-phase Total DDT (a solid) in the unsaturated zone is not considered by this FS. Shallow soils in the unsaturated zone (i.e., 0 to 10 feet bgs) that are significantly impacted with Total DDT will be addressed by the Soil FS (currently in progress). More than 500,000 pounds of sorbed-phase Total DDT are estimated to be present in the unsaturated soils at the Site (see Soil FS for further details).

2.2.3 OTHER VOCS

Although MCB is the predominant VOC detected in soils and soil gas at the Property, a small number of other VOCs were detected in excess of their respective industrial PRGs (EPA, 2008e), including chloroform, 1,4-DCB, PCE, benzene, and carbon tetrachloride. These VOCs occur in substantially lower concentrations in the unsaturated zone, are not a component of the Montrose DNAPL, and do not significantly contribute to the mass of VOCs in the subsurface. Nonetheless, some of these VOCs may affect DNAPL remedy evaluation, and therefore, the occurrence of these VOCs in the unsaturated zone is summarized below. Specifically, chloroform was the second highest vapor-phase contaminant detected in soil vapors extracted during an SVE pilot test conducted at the Site in 2003 and will need to be considered during selection of an off-gas treatment technology.

<u>Chloroform</u>

- In unsaturated soils, chloroform was detected in concentrations up to 160 mg/kg as shown in **Figure 2.5**. The highest chloroform concentrations occur over a limited area in the northeast corner of the CPA at borings 14D, C15, and C9. The highest chloroform concentrations in this area occur within the low permeability PD soils, with up to 160 mg/kg at 10 feet bgs and up to 130 mg/kg at 20 feet bgs. Outside the CPA, the highest concentrations of chloroform, up to 11 mg/kg, occur to the southeast at borings C45 and C50. Chloroform concentrations in the PD and PVS/unsaturated UBA are mapped separately in **Figures 2.6a and 2.6b**.
- In soil gas, chloroform was detected in concentrations up to 35 ppmv at 5-feet bgs (SG12), 90 ppmv at 15-feet bgs (SG16A), and 2,253 ppmv at 35-feet bgs (SG08). The highest concentrations of chloroform in soil gas occur at 35 feet bgs in SG08, located in the northeast corner of the CPA, and in SG29, located southeast of the CPA. Maps of chloroform in soil gas are provided as **Figures 2.7a through 2.7c**.

<u>1,4-Dichlorobenzene</u>

- In unsaturated soils, 1,4-DCB was detected in concentrations up to 260 mg/kg as shown in **Figure 2.8**. The highest 1,4-DCB concentrations occur over a limited area in the CPA at borings

24D, C15, and C33. The highest 1,4-DCB concentrations in this area occur within the low permeability PD soils, with up to 240 mg/kg at 7 feet bgs, up to 260 mg/kg at 10 feet, and up to 190 mg/kg at 20 feet bgs. Outside the CPA, the highest concentrations of 1,4-DCB, up to 44 mg/kg, occur in the southeast corner of the Property at boring C64. 1,4-DCB concentrations in the PD and PVS/unsaturated UBA are mapped separately in **Figures 2.9a and 2.9b**.

- Only very low concentrations of 1,4-DCB were detected in soil gas; this contaminant has a low vapor pressure under 2 mm Hg at 20°C. In soil gas, 1,4-DCB was detected in concentrations up to 2 ppmv at 5-feet bgs (SG16A), 4 ppmv at 15-feet bgs (SG16A), and 2 ppmv at 35-feet bgs (SG16A). Maps of 1,4-DCB in soil gas are provided as **Figures 2.10a through 2.10c**.

PCE

- In unsaturated soils, PCE was detected in concentrations up to 34 mg/kg as shown in **Figure 2.11**. The highest PCE concentrations occur in isolated areas at the Property in borings C14, C33, and C55. Nearly all of these PCE concentrations occur within the low permeability PD soils. PCE concentrations in the PD and PVS/unsaturated UBA are mapped separately in **Figures 2.12a and 2.12b**.
- In soil gas, PCE was detected in concentrations up to 5 ppmv at 5-feet bgs (SG12), 60 ppmv at 15-feet bgs (SG25), and 841 ppmv at 35-feet bgs (SG28). Maps of PCE in soil gas are provided as **Figures 2.13a through 2.13c**. The PCE in soil gas originates from the JCI Property, with the highest concentrations occurring along the Montrose/JCI property boundary. PCE is a known contaminant of concern in soil and soil gas at the JCI property (Levine-Fricke, 1995).

Benzene

- In unsaturated soils, benzene was found to exceed the 2008 EPA Industrial PRG in only two samples collected from boring S204, located in the CPA (**Figure 2.14**). Benzene concentrations of 10 and 20 mg/kg were detected in samples collected at 26 and 26.5 feet bgs in this boring. No other unsaturated soil samples exhibited benzene concentrations in excess of the 2008 EPA Industrial PRG.
- In soil gas, benzene was detected in concentrations up to 2 ppmv at 5-feet bgs (SG14), 2 ppmv at 15-feet bgs (SG25), and 116 ppmv at 35-feet bgs (SG29). Maps of benzene in soil gas are provided as **Figures 2.15a through 2.15c**.

Carbon Tetrachloride

- In unsaturated soils, carbon tetrachloride was found to exceed the 2008 EPA Industrial PRG in only two samples collected from boring C15, located in the CPA (**Figure 2.16**). Carbon tetrachloride concentrations of 2.8 and 3.2 mg/kg were detected in samples collected at 10 and 20 feet bgs in this boring. No other unsaturated soil samples contained carbon tetrachloride concentrations in excess of the 2008 EPA Industrial PRG.
- In soil gas, carbon tetrachloride was detected in concentrations up to 0.35 ppmv at 5-feet bgs (SG12), 0.83 ppmv at 15-feet bgs (SG25), and 40 ppmv at 35-feet bgs (SG28). The carbon tetrachloride in soil gas originates from the JCI Property, with the highest concentrations occurring along the Montrose/JCI property boundary. Carbon tetrachloride is a known contaminant of concern in soil and soil gas at the JCI property (Levine-Fricke, 1995). Maps of carbon tetrachloride in soil gas are provided as **Figures 2.17a through 2.17c**.

2.2.4 TOTAL DDT

Total DDT concentrations in the unsaturated zone are mapped in **Figure 2.18**. Relatively high concentrations of Total DDT, up to 57,000 mg/kg (at PSB-5), were detected in soils over the majority of the Property. The highest concentrations of Total DDT occur within the raised building pads and subsurface soils within the CPA and the northwest corner of the Property.

DDT is relatively insoluble in water, adsorbs strongly to soil grains, and is not volatile. Because of these properties, DDT will tend to accumulate in shallow, near-surface soils. However, as demonstrated by the DNAPL, DDT can migrate vertically downward as a component of a MCB/DDT liquid mixture. Therefore, relatively high concentrations of DDT at depth suggest the possible presence of DNAPL. Total DDT concentrations in the unsaturated zone between 11 and 60 feet bgs are mapped in **Figure 2.19** and summarized below; this map excludes Total DDT in the upper 10 feet of the unsaturated zone. The DDT that is present from 0 to 10 feet bgs will be addressed as part of the pending Soil FS.

<u>Total DDT (11 to 60 feet bgs)</u>

- Relatively high concentrations of Total DDT occur throughout the CPA, including:
  - Up to 57,000 mg/kg at PSB-5 in the northeast corner of the CPA,
  - Up to 9,406 mg/kg at S-101/101A within the former water recycling pond and southwestern portion of the CPA,
  - Up to 13,000 mg/kg at PSB-15 located in the southern portion of the CPA, and
  - Up to 1,498 mg/kg at C33 located at the eastern edge of the CPA.
- Relatively low concentrations of Total DDT occur outside the CPA source areas within the 11-60 foot interval of the unsaturated zone. The highest Total DDT concentration outside the CPA source areas over this interval is 30 mg/kg at C50, located southeast of the CPA.

2.3 GROUNDWATER CONTAMINATION IN THE UPPER BELLFLOWER AQUITARD

Because the distribution of dissolved DNAPL components can be used to infer the extent and distribution of DNAPL, an overview of groundwater contamination in the UBA is presented in this section. For a detailed discussion of regional groundwater contamination at the Site, the reader is referred to the RI Report and subsequent monitoring reports (EPA, 1998; H+A, 2004c and 2007a).

2.3.1 MCB

The lateral extent of the MCB plume in the UBA is depicted in **Figure 2.20** and is based on groundwater samples collected in October 2006 as well as the most recent historical results (i.e., for wells not sampled in October 2006). On-Property the highest concentrations of MCB on-Property (up to 380,000 ug/L at well MW-2) occur within the CPA. The highest concentration approaches the solubility limit for MCB in water, which is approximately 500,000 ug/L. A MCB plume, i.e. greater than 10,000 ug/L, extends from the property towards the southeast, with a concentration of 84,000 ug/L being detected at monitoring well MW-1 in the southeast corner of the Property. The small lateral extent of MCB in the UBA, approximately 1,500 to 2,000 feet downgradient from the DNAPL source areas, is attributed to low hydraulic conductivity, and consequently low horizontal groundwater flow velocity within the UBA. Groundwater flow within the UBA is primarily in the horizontal direction, with only a small downward vertical gradient between the UBA and underlying BFS.

2.3.2 OTHER VOCS

Other VOCs detected in groundwater samples collected from on-Property wells screened in the UBA during the October 2006 monitoring event include:

- Benzene at 2,700 ug/L (MW-1),
- Chloroform from 6.1 ug/L to 9,600 ug/L (MW-1, MW-3, and MW-4),
- Carbon Tetrachloride at 2.6 ug/L (MW-3),
- PCE from 30 ug/L to 650 ug/L (MW-3 and MW-4),
- TCE from 110 ug/L to 170 ug/L (MW-3 and MW-4), and
- 1,1-DCE at 6.1 ug/L (MW-3).

The VOCs detected during the October 2006 monitoring event are generally consistent with historical detections in the UBA. Further information regarding other VOCs detected during the October 2006 sampling event can be found in the monitoring report for that event (H+A, 2007a).

2.3.3 DDT

DDT is hydrophobic and relatively insoluble in groundwater. Without MCB as a co-solvent, DDT will adsorb strongly to soil grains and be relatively immobile in groundwater. DDT has been infrequently detected in groundwater within the UBA despite having been mobilized to the saturated zone by MCB. The concentration of DDT in groundwater in the UBA is mapped in **Figure 2.21**.

2.3.4 pCBSA

pCBSA is an organic salt and is highly soluble in groundwater, up to approximately 150,000 mg/L. pCBSA is stable in groundwater and migrates readily with groundwater flow and through dissolution. pCBSA is only a trace constituent in DNAPL, and the occurrence of this contaminant in groundwater is not related to DNAPL. However, the presence of pCBSA in groundwater will affect DNAPL remedial technologies and process options considered in this FS. pCBSA concentrations in the UBA are mapped in **Figure 2.22**. The highest concentrations of pCBSA of 470,000 ug/l were detected at well MW-2, within the CPA, and well MW-1, at the southeast corner of the site.

2.3.5 Inorganics

Inorganics in groundwater, in addition to DDT precipitation, contributed to equipment fouling during DNAPL extraction testing in 2004 and 2005. Equipment fouling posed a significant challenge to completing the short-term extraction test and will impact DNAPL remedial technologies and process options considered in this FS. For this reason, the following inorganic concentrations are presented below, and additional details regarding inorganic concentrations are available in the RI Report (EPA, 1998). Although metals have been detected in groundwater, none of their concentrations are high enough to impact DNAPL remedial technologies or process options, other than possibly arsenic. The concentration ranges of common inorganics detected in on-Property wells, located within or near DNAPL-impacted areas, are summarized below:

- Total Dissolved Solids (TDS) concentrations in on-Property UBA wells ranged from 860 mg/L (MW-3) to 14,000 mg/L (MW-2) and were generally highest in wells located within the CPA.
- Calcium concentrations in on-Property UBA wells ranged from 162 mg/L (MW-3) to 590 mg/L (MW-1) and did not significantly vary across the Property.
- Chloride concentrations in on-Property UBA wells ranged from 220 mg/L (MW-3) to 2,400 mg/L (MW-2) and were generally highest in wells located within the CPA.
- Sulfate concentrations in on-Property UBA wells ranged from 18 mg/L (MW-3) to 4,800 mg/L (MW-2) and were generally highest in wells located within the CPA.
- Bicarbonate concentrations in on-Property UBA wells ranged from 420 mg/L (MW-4) to 770 mg/L (MW-2) and did not significantly vary across the Property.
- Nitrate (as NO_3) concentrations in on-Property UBA wells ranged from <0.4 mg/L (MW-1, 2, and 4) to 7 mg/L (MW-5) and were low or non-detectable in all on-Property wells.

- Relatively neutral acidic conditions, pH values ranging from 6.5 to 7.1 units, have been reported in on-Property UBA wells.
- Arsenic concentrations in on-Property UBA wells ranged from <0.002 mg/L (MW-5) to 0.16 mg/L (MW-2). The arsenic concentrations reported at MW-2 and MW-1 (0.014 mg/L) exceed the Federal maximum contaminant level of 0.01 mg/L.

2.4 GROUNDWATER CONTAMINATION IN THE BELLFLOWER SAND

Some technologies being considered for remediation of the DNAPL-impacted soils may include components that extend into the BFS. Therefore, discussion of the water quality in this zone is presented to provide background for assessing those remedial alternatives. For a detailed discussion of regional groundwater contamination at the Site, the reader is referred to the RI and subsequent monitoring reports (EPA, 1998; H+A, 2004c and 2007a).

2.4.1 MCB

The lateral extent of the MCB plume in the BFS is mapped in **Figure 2.23** and is based on the most recent groundwater samples collected in October 2006. The highest concentration of MCB detected in the BFS at the Property was 73,000 ug/L at well BF-2 located at the southern Property boundary. Within the CPA, MCB was detected at 19,000 ug/L in well BF-9. Concentrations of MCB exceeding the California MCL in the BFS extend several thousand feet downgradient of the source area, and the large lateral extent is attributed to high hydraulic conductivity and a high horizontal groundwater flow velocity within the BFS beneath the Site.

2.4.2 OTHER VOCS

Other VOCs detected on-Property in groundwater samples collected from the BFS during the 2006 monitoring event include:

- TCE was detected at 1,200 ug/L in well BF-3 located east of the CPA.
- Chloroform was detected at 790 ug/L in well BF-2 located at the southern Property boundary.

2.4.3 DDT

The concentration of DDT in groundwater in the BFS is shown in **Figure 2.24** and is based on data collected in 2004. Only trace level concentrations of DDT were detected in the BFS, including 4.4 ug/L in monitoring well BF-9 located within the CPA. DDT was also detected at concentrations ranging from 1 to 3 ug/L in monitoring wells located immediately upgradient and downgradient of the CPA.

2.4.4 pCBSA

The lateral extent of the pCBSA plume in the BFS is mapped in **Figure 2.25** and is based on the October 2006 monitoring event. The highest concentration of pCBSA detected in the BFS at the Property was 76,000 ug/L at well BF-9 located within the CPA.

2.5 EXTENT OF DNAPL

Field investigations have been conducted to assess the vertical and lateral extent of DNAPL beneath the Site. Soil borings drilled prior to 2003 were evaluated for evidence of DNAPL by visual inspection and laboratory analysis. Soil borings drilled after 2003 as part of the DNAPL Reconnaissance Investigation Program were evaluated for evidence of DNAPL using not only visual inspection of core but also staining on a hydrophobic dye-impregnated fabric (Flexible Liner Underground Technologies [FLUTe] ribbon), laboratory analysis of discrete soil samples, and organic vapor analyzer (OVA) field soil headspace measurements (H+A, 2004b). These lines of evidence provide information related to the definite and possible presence of DNAPL in the subsurface. The following guidelines were used in evaluating the various lines of evidence for assessing DNAPL occurrence at the Site:

DNAPL Occurrence Guidelines

Method	**DNAPL Not Present**	**DNAPL Possibly Present**	**DNAPL Definitely Present**
Primary			
Visual	Not Visible	Not Visible	Oily Sheen
FLUTe Ribbon	No Staining	No Staining	Ribbon Staining
Secondary			
Laboratory Results[1]	<180 mg/kg MCB or <60 mg/kg Total DDT	180 to 1,000 mg/kg MCB or 60 to 1,000 mg/kg Total DDT	>1,000 mg/kg MCB or >1,000 mg/kg Total DDT
OVA readings[1]	<1,500 ppmv	1,500 to 10,000 ppmv	>10,000 ppmv

Notes:
[1] The rationale for the criteria for laboratory results and OVA readings maybe found in H+A, 2004b.
mg/kg = milligrams per kilogram
ppmv = parts per million vapor
FLUTe = Flexible Liner Underground Technologies

2.5.1 ESTIMATED LATERAL EXTENT OF DNAPL

The lateral extent of DNAPL varies between the unsaturated and saturated zones, as described below. Based on recent and historic investigations, the area directly beneath the CPA has the most DNAPL in both the unsaturated zone and the saturated UBA. The lateral extent of DNAPL occurs fully within the Technical Impracticability Waiver Zone established by the EPA as part of the ROD (EPA, 1999). A summary of DNAPL characterization results is provided in **Appendix D**. Additional information regarding the extent of DNAPL in the unsaturated zone is provided in the report summarizing the results of the DNAPL reconnaissance investigation (H+A, 2004b).

Unsaturated Zone (0 to 60 feet bgs)

The majority of the DNAPL in the unsaturated zone occurs in the CPA as shown in **Figure 2.26**. This figure depicts both the definite and possible extents of DNAPL in the unsaturated zone. The definite extent of DNAPL is estimated to be approximately 57,000 square feet and encompasses the majority of the CPA including the former water recycling pond and raw materials storage area. The area is bounded by borings PSB-15, S302F, and PSB-10 to the south and by borings SSB-7, PSB-5, PSB-4, and SSB-4 to the north. DNAPL was visually observed at 57 feet bgs in boring PSB-5 and at 17 feet bgs in boring SSB-4.

The possible extent of DNAPL is estimated to be approximately 79,000 square feet and encompasses areas surrounding by borings PSB-6 to the north, PSB-16 to the west, and several borings to the south. Additionally, two isolated small areas at C59 and C64 located in the unsaturated zone at the southeastern corner of the Property were found to have MCB/Total DDT concentrations meeting the criteria for possible DNAPL, although it is unlikely that DNAPL is present at these locations. Some of the DNAPL characterization criteria, specifically soil analytical results and field headspace concentrations, are not as reliable in characterizing DNAPL in the unsaturated zone. The presence of DDT and MCB in shallow unsaturated soils does not uniquely distinguish DNAPL, as those contaminants could have been released individually. High concentrations of DDT, well above the DNAPL characterization criteria, are present in shallow soils (0-10 feet bgs) over the majority of the Property. Additionally, VOCs in unsaturated soils will volatilize into soil gas in accordance with their physical properties (i.e. partial pressures) and can migrate or diffuse in soil gas over larger areas. For this reason, field headspace concentrations are not as a reliable a method for distinguishing DNAPL in the unsaturated zone (as other methods, i.e., visual staining or FLUTe ribbon).

Saturated UBA (60 to 105 feet bgs)

DNAPL occurs over a larger area within the saturated zone than observed within the unsaturated zone. The definite presence of DNAPL in the saturated UBA occurs over an area of approximately 150,000 square feet as shown in **Figure 2.27**. This area encompasses the majority of the former CPA, including the water recycling pond and raw materials storage areas. As shown in this figure, DNAPL extends east of the former CPA, presumably due to DNAPL migration along the top of low permeability silt layers in the down-slope direction. The extent of definite DNAPL within the saturated UBA is described as follows:

- The most significant DNAPL impacts within the saturated UBA occur at wells UBT-1 through UBT-3, located in the CPA near the former water recycling pond.
- Definite DNAPL occurs up to approximately 180 feet east of the former CPA and adjacent railroad tracks at borings TSB-3, TSB-8, and SSB-12.
- Definite DNAPL does not extend significantly west of the former water recycling pond at borings PSB-9 and PSB-17.
- Definite DNAPL extends to the northern Property boundary at borings TSB-2 and SSB-2; DNAPL is estimated to extend approximately 30 feet north of the Property boundary (i.e. onto the adjacent former Boeing property) based on the definite occurrence of DNAPL at TSB-2.
- Definite DNAPL extends southeast of the former CPA at borings C44, PSB-18, and PSB-14.

The possible presence of DNAPL occurs over a larger area than the definite DNAPL and encompasses approximately 160,000 square feet as shown in **Figure 2.27**. The possible presence of DNAPL occurs to the east at SSB-3 and TSB-11 and to the south at TSB-9.

2.5.2 ESTIMATED VERTICAL EXTENT OF DNAPL

DNAPL has been definitively detected from a minimum of 7 feet bgs in the unsaturated zone to a maximum of 101.5 feet bgs in the saturated UBA (H+A, 1999 and 2004b). The predominant DNAPL-impacted zone is the saturated portion of the UBA at depths ranging from approximately 75 to 95 bgs (H+A, 2004b). Cross-sections have been constructed showing the heterogeneous interbedded nature of the UBA and the distribution of DNAPL within the unsaturated zone and saturated UBA (**Figures 1.11 through 1.13**). The majority of the observed DNAPL is perched on low permeability silt layers throughout the UBA.

<u>BFS</u>

In 1988, six soil borings were drilled to the base of the BFS within the CPA. The data obtained during the 1988 program were presented in a technical memorandum to EPA (H+A, 2004a) and are summarized as follows:

- DNAPL was not visually observed within the BFS in core samples from the 6 deep soil borings advanced in the CPA beneath the area known to contain DNAPL in the UBA.
- The maximum concentration of MCB detected in BFS soil was 51 mg/kg in a soil sample collected at 125.3 feet bgs.
- The maximum concentration of DDT detected in BFS soil was 130 mg/kg in a soil sample collected at 126.5 feet bgs.

When the data collected in 1988 were re-evaluated in connection with the DNAPL characterization criteria established in 2003/2004 for the Reconnaissance Program, the DDT result of 130 mg/kg in a soil sample collected at 126.5 feet bgs would be interpreted as indicating the possible presence of DNAPL at that location. The RI Report provides some discussion of the possible presence of DNAPL in the BFS. The report states that *"DNAPL was not directly observed in the underlying BFS, however, its likely presence could be inferred from groundwater concentrations (EPA, 1998)."* The report goes on to indicate that *"the occurrence of DDT at these concentrations* (in a soil sample at 130 mg/kg) *may be related to the past or present occurrence of DNAPL, or may be a remnant of having drilled through high concentrations in the overlying DNAPL impacted zone (EPA, 1998)."* To further assess the presence of DNAPL in the BFS, additional field investigations were conducted in 2008.

2008 Field Investigation for Presence of DNAPL in BFS

In March 2008, passive diffusion bags (PDBs) were placed in BFS monitoring wells BF-2, BF-4, and BF-9 (**Figure 2.1**) to determine the vertical profile of dissolved contaminants within the BFS. These wells were selected because they are either beneath the known footprint of DNAPL in the UBA (BF-9) or downgradient of the extent of DNAPL in the UBA (BF-2 and BF-4). After 2 weeks, the passive diffusion bags were removed from the wells and analyzed for the presence of VOCs by EPA 8260B. Results are summarized as follows:

2008 Passive Diffusion Bag Results in BFS

BFS Monitoring Well	Passive Diffusion Bag Sample Depth (feet bgs)	MCB Concentration (ug/L)
BF-2	114-115.5	52,000
	118.25-119.75	33,000
	122.5-124	53,000
BF-4	112-113.5	13,000
	116.25-117.75	21,000
	120.5-122	19,000
BF-9	107-108.5	28,000
	112-113.5	64,000
	117.5-119	79,000
	126-127.5	78,000

The results of BF-2 and BF-4 did not exhibit an increasing trend of MCB concentration as would be expected if DNAPL were present at the base of the BFS. However, the concentrations of MCB did increase with depth in the samples collected from shallow to deeper depths in BF-9.

Based on the results of the PDB samples, two soil borings were drilled immediately outside the known extent of DNAPL in the UBA at the locations shown in **Figure 2.28** (H+A, 2008c). Boring BFSB-1 was drilled south of the CPA and between monitoring wells BF-2 and BF-9. Boring BFSB-2 was drilled southeast of the CPA and near monitoring well BF-4. Rotosonic drilling methods were used to continuously core the soils during drilling to a total depth of 125 feet bgs. The core was logged and tested for the presence of DNAPL in accordance with the methods established during the DNAPL Reconnaissance Program. Depth discrete groundwater samples were collected between 98 and 125 feet using SimulProbe® sampling device. The samples were analyzed for the presence of VOCs by EPA 8260B, pesticides by EPA 8081A, and pCBSA by EPA 314.0 modified. Results are presented in **Table 2.1** and summarized as follows:

BFSB-1

- No DNAPL was visually observed or detected by the FLUTe ribbon.
- All soil sample headspace concentrations were relatively low, with a maximum concentration of 118 ppmv.
- At the base of the UBA, the MCB concentration was 150,000 ug/L at 98.5 feet and 19,000 ug/L at 109.5 feet bgs. Within the BFS, between 109.5 and 125 feet bgs, MCB concentrations then consistently increased to a maximum value of 100,000 ug/L at 125 feet.
- pCBSA concentrations at the base of the UBA were 720,000 ug/L at 98.5 feet and 33,000 ug/L at 109.5 feet. Within the BFS, between 109.5 and 125 feet, pCBSA concentrations consistently increased to a maximum value of 320,000 ug/L at 125 feet.
- Total DDT was detected in low concentrations between 0.15 ug/L at 109.5 feet and 8.84 ug/L at 120 feet bgs.

BFSB-2

- No DNAPL was visually observed or detected by the FLUTe ribbon.
- All soil sample headspace concentrations were relatively low, with a maximum concentration of 81 ppmv.
- The MCB concentration at the base of the UBA was 13,000 ug/L at 100 feet bgs. Within the BFS, from 110 to 124.5 feet bgs, MCB concentrations ranged between 20,000 ug/L and 45,000 ug/L.
- The pCBSA concentration at the base of the UBA was 63,000 ug/L at 100 feet bgs. Within the BFS, from 110 to 124.5 feet bgs, pCBSA concentrations ranged between 47,000 ug/L and 130,000 ug/L.
- Total DDT was detected in low concentrations between 0.36 ug/L at 100 feet and 7.5 ug/L at 120 feet bgs.

No definite DNAPL was detected within the UBA or BFS during drilling of BFSB-1 and BFSB-2. However, an increasing vertical concentration profile was observed at BFSB-1, which can be indicative of

DNAPL in the BFS, and the concentrations at the base of the BFS were approximately 20% of the MCB solubility limit. EPA believes the concentration profile within the BFS is indicative of the presence of DNAPL at the base of the BFS (EPA, 2008b). However, the pCBSA concentrations exhibited the same concentration profile as MCB, suggesting that the profile is not the result of DNAPL within the BFS since pCBSA is not a component of DNAPL. The significance of this data is that if DNAPL is present within the BFS, it will provide a continuing source of MCB to groundwater regardless of the amount of DNAPL remediation accomplished within the overlying UBA. Given the limited evidence of DNAPL occurrence in the BFS, the mass of DNAPL potentially present in the BFS would be significantly less than the mass occurring within the overlying UBA, as indicated in Section 2.5.5.

2.5.3 DNAPL Concentration

During the Reconnaissance Investigation Program (H+A, 2004b), a number of DNAPL-impacted soil samples were collected for laboratory analysis of MCB and Total DDT by EPA Method 8270C modified. During supplemental soil investigation activities in 2005 (Earth Tech, 2007b), a small number of additional soil samples from the saturated UBA were characterized for the presence of MCB by EPA 8260B and for Total DDT by EPA 8081A. For the purposes of this FS, the sum of the MCB and Total DDT concentrations in saturated soils, where liquid-phase DNAPL occurs, is referred to as the "DNAPL concentration". DNAPL concentrations detected in the saturated UBA are provided in **Table 2.2**, mapped in **Figure 2.29**, and summarized as follows:

- The highest DNAPL concentrations, greater than 50,000 mg/kg, occur within the CPA between boring S-101/101A in the water recycling pond and SSB-4 located in the northeast corner of the CPA.
- One high DNAPL concentration (103,000 mg/kg) was reported at SSB-12 located southeast of the CPA.
- Moderate DNAPL concentrations, greater than 10,000 mg/kg, occur over the southern portion of the CPA at borings C30 and PSB-15, 18, and 19. Moderate DNAPL concentrations additionally occur east of the CPA at PSB-2, 11, and 14 and TSB-3 and 8.
- Low DNAPL concentrations, below 1,000 mg/kg, were reported at DP-1, 2, 4, and 8, located immediately east wells UBT-1 through UBT-3. It is uncertain whether the low concentrations reported at these borings are accurate or whether the limited analytical program or direct-push drilling methods have resulted in conservatively low concentrations. The rotosonic drilling methods used at all other DNAPL investigation borings (identified with prefix PSB, SSB, TSB, and C) were found to provide more reliable and representative results.
- The areas represented by possible DNAPL all have low DNAPL concentrations below 1,000 mg/kg.

Characterization of DNAPL concentration in subsurface soils was not an objective of the Reconnaissance Investigation Program. The primary objective of that program was to characterize the presence of the DNAPL, not quantify the thickness or concentration of the DNAPL. As a result, only a limited number of DNAPL-impacted soil samples were collected for laboratory analysis, only one sample per boring in many cases. Given the limited analytical data available for DNAPL-impacted soil samples, there is a greater uncertainty related to the distribution of DNAPL concentrations within the saturated UBA.

2.5.4 DNAPL THICKNESS

While the vertical extent of DNAPL-impacts at the Site is from 7 to 101.5 feet bgs (as described in Section 2.5.2), DNAPL does not fully occupy pore spaces throughout the soil column. Instead, DNAPL occurs in the form of ganglia and pools over relatively thin intervals that make up only a fraction of the total soil column. In order to estimate the mass of DNAPL at the Site, it is necessary to estimate the DNAPL thickness, defined as being the sum of DNAPL-impacted soil intervals within the soil column.

Where DNAPL was visibly observed in soil cores or detected using the FLUTe ribbon, the thickness is reasonably certain, although some level of uncertainty remains. The FLUTe ribbon may not detect DNAPL since it only contacts a portion of the soil core. In the saturated zone, soil headspace can be used to determine the presence of VOCs or DNAPL, but it does not provide any information regarding thickness. Similarly, soil analytical data can determine the presence of DNAPL, but the available sample volume is very small and does not provide information regarding DNAPL thickness. Therefore, while the extent of DNAPL is reasonably well defined by the reconnaissance borings, estimates of thickness are less certain in some cases. The estimates of DNAPL thickness has to be guided to some extent by professional judgment.

DNAPL thickness was estimated by H+A using two different approaches, one conservative and one liberal, to provide a range of candidate thicknesses. However, in comments made by EPA in December 2008 (EPA, 2008g), EPA believes that the conservative approach resulted in an underestimate of the DNAPL thickness. Therefore, in accordance with EPA comments, only the liberal approach for estimating DNAPL thickness is presented in the FS as follows:

<u>Liberal Evaluation of Thicknesses</u>

For the liberal scenario, the following was assumed for DNAPL thickness:

- Visual observation = observed thickness
- FLUTe ribbon = thickness of stain

- DNAPL observed at base of sand layer = 0.1 feet for thin layers and up to 1.5 feet for thicker layers (approximately 50% of the layer thickness)
- DNAPL observed throughout layer = thickness of entire layer
- Alternating evidence of DNAPL in a layer = thickness equal to half the distance between non-DNAPL depths

Professional judgment was used to assign thickness values for the liberal estimate (conservatively high estimate, if anything). In some cases, the liberal thickness estimate was greater than the DNAPL thickness observed in a soil core or on the FLUTe ribbon. Additionally, DNAPL thickness greater than a minimum value of 0.1-feet was assigned to soils exhibiting high headspace concentrations or laboratory results. The liberal thickness of DNAPL estimated to occur in each boring (cumulative observed thickness) is provided in **Table 2.3** and mapped in **Figure 2.31**. Thickness varied from 0.25 to 14.15 feet (H+A, 2008e and 2008f). The thickest DNAPL occurred within the CPA, near the former wastewater pond at UBT-1 through UBT-3, at PSB-9 located west of the former wastewater pond, and at the former raw materials storage area near PSB-5. DNAPL thickness to the east of the CPA was less than or equal to 2 feet.

2.5.5 ESTIMATED DNAPL MASS

Based on the extent, concentration, and liberal estimate of DNAPL thickness, the mass of DNAPL was estimated as described in this section.

<u>Unsaturated Zone</u>

The mass of MCB in the unsaturated zone was estimated as reported in Section 2.2. MCB concentrations detected in DNAPL-impacted soil samples at PSB-5 and SSB-4 were included in that estimate and are not duplicated here as a separate DNAPL mass estimate.

<u>Saturated UBA (60 to 105 feet bgs)</u>

Without information regarding the amount of contaminant mass released at a site, it can be difficult to reliably estimate the total mass of contaminant in the subsurface. However, the amount of DNAPL mass (i.e., MCB and DDT) in the saturated UBA was estimated using the area of DNAPL-impacts to soil, DNAPL thicknesses, DNAPL concentrations, and soil bulk density, as described below.

Liberal DNAPL Mass Estimate

The DNAPL mass was estimated to be approximately 796,100 pounds as shown in **Appendix E** (H+A, 2008e). This mass estimate is based on the liberal DNAPL thicknesses presented in Section 2.5.4, the DNAPL concentrations presented in Section 2.5.3, and the area of DNAPL-impacts presented in Section 2.5.1. Using the measured density of the Montrose DNAPL at 22°C (1.25 g/cc), the equivalent volume of DNAPL occurring within the saturated UBA is estimated at 76,000 gallons.

Given the uncertainty associated with DNAPL thickness and concentrations, the DNAPL mass could be as much as 50% higher or up to 1.2 million pounds. However, comparing the liberal thickness estimates against theoretical thickness amounts (determined using DNAPL concentrations and capillary pressure data), the liberal thickness estimates appear to be over-estimated, if anything, in approximately two-thirds of the DNAPL occurrences (H+A, 2009c). Therefore, the DNAPL mass estimate is not believed to be significantly underestimated as suggested by EPA in comments made in a letter dated December 23, 2008 (EPA, 2008g). Responses to EPA comments regarding the estimated DNAPL mass at the Site are provided in **Appendix G**.

Assuming a residual DNAPL saturation of 18.9% for the entire DNAPL-impacted area, the amount of mobile DNAPL mass was estimated as shown in Appendix E and summarized as follows:

- Mobile DNAPL mass is estimated to be roughly 221,800 pounds or 21,000 gallons
- Residual DNAPL mass is estimated to be roughly 574,200 pounds or 55,000 gallons
- Total DNAPL mass (mobile plus residual) is estimated at 796,100 pounds or 76,000 gallons

2.6 DNAPL TREATABILITY AND MODELING STUDIES

The nature and extent of DNAPL occurrence at the Montrose Site was presented in Sections 2.1 through 2.5. This section summarizes the treatability and modeling studies conducted to evaluate candidate DNAPL remedial technologies at the Site. These studies provide valuable information for evaluating remedial technologies identified in Section 3 and preliminarily screened in Section 4. Additionally, some of these studies provide evidence of mobile DNAPL occurrence at the Site, specifically passive DNAPL accumulation (Section 2.6.2) and hydraulic displacement field pilot testing (Section 2.6.3).

In some cases, preliminary screening, such as discussions with technology vendors or literature research, provides sufficient information to evaluate the implementability and potential effectiveness of DNAPL remedial technologies. However, for other remedial technologies, preliminary screening techniques were not sufficient to fully understand the strengths and limitations of the technology as applied to the Montrose Site. In these cases, theoretical modeling, bench-scale testing, and/or field-scale pilot testing was conducted to better assess the implementability, effectiveness, and costs related to the DNAPL remedial technologies. The following sections summarize the results of treatability and modeling studies conducted to evaluate DNAPL remedial technologies in support of this FS.

2.6.1 MASS FLUX EVALUATION

Long-term hydraulic containment of dissolved-phase MCB within the TI Waiver Zone is required by the groundwater ROD. As groundwater flows through the DNAPL-impacted area, the MCB component of the DNAPL will solubilize into groundwater. Hydraulic containment of the dissolved-phase MCB is required in the long-term to prevent migration of dissolved-phase MCB outside the TI Waiver Zone and into areas treated by the groundwater remedy. Groundwater flow at the Site occurs primarily in the horizontal direction (the vertical groundwater velocity between the UBA and BFS is very small compared with the horizontal velocity).

To support remedy evaluation, the duration of containment within the saturated zone that will be required following a DNAPL remedy was estimated using a numerical method (H+A, 2008e). The Falta Method (Falta et.al., 2005) was used to estimate containment zone timeframes assuming a Power Function with a first order decay (i.e., exponential decline of the contaminant mass flux over time). The duration required for hydraulic containment is dependent on the mass of the DNAPL-phase MCB within the saturated zone, and containment zone timeframes were estimated assuming varying amounts of MCB mass reduction in the UBA in the short-term. Three different treatment scenarios were considered including hydraulic displacement (which removes mobile DNAPL mass), thermal remediation within a focused treatment area (same footprint as for hydraulic displacement, which is the estimated extent of mobile DNAPL), and thermal remediation over the entire DNAPL-impacted area.

The containment timeframes estimated in the September 4, 2008 version of the H+A memorandum were originally based on the average DNAPL mass in the saturated UBA (average of conservative and liberal). As explained in Section 2.5.4 and based on EPA comments, only the liberal DNAPL mass is presented in this FS. Therefore, the containment timeframes were re-estimated using only the liberal DNAPL mass estimate as the basis, and a revised H+A memorandum is provided as **Appendix G** in this FS (H+A, 2009c). In this revised memorandum, three different MCB mass reduction percentages were assumed (60%, 80%, and 90%) for each of the three treatment scenarios. These mass reduction assumptions apply to the DNAPL-phase MCB and exclude dissolved-phase MCB nor any impact associated with MCB in the unsaturated zone. The revised estimates for hydraulic containment timeframes using only the liberal DNAPL mass and the 60% to 90% mass reduction assumptions are summarized as follows:

Hydraulic Containment Timeframe Estimates

	Assumed MCB Mass Reduction*		**Containment Timeframe (years)**
	(pounds)	**(%)**	
Containment Only	0	0%	4,900
Hydraulic Displacement (equivalent to 60, 80, and 90% of mobile DNAPL mass or 110,900 pounds; MCB component only)	66,550	17%	4,700
	88,700	22%	4,700
	99,800	25%	4,700
Thermal Remediation, over Focused Treatment Area (equivalent to 60, 80, and 90% of MCB mass in focused treatment area or 236,800 pounds)	142,100	36%	4,500
	189,500	48%	4,400
	213,150	54%	4,300
Thermal Remediation, Entire DNAPL-Impacted Area (MCB mass of 398,000 pounds)	238,800	60%	4,200
	318,400	80%	3,600
	358,200	90%	3,100

Notes:
* Based on estimated MCB mass (DNAPL-phase) in saturated UBA; 50% of 796,100 pounds or 398,000 pounds
See Section 5.1.1 and Appendix G for further details

Without any reduction in the DNAPL mass, containment within the UBA will be required for approximately 4,900 years. Under a hydraulic displacement remedy, containment zone timeframes are reduced to approximately 4,700 years. Under a thermal remedy within a focused treatment area equivalent to the mobile DNAPL footprint, containment zone timeframes are reduced to between approximately 4,300 and 4,500 years. Under a thermal remedy over the entire DNAPL-impacted area, containment zone timeframes are reduced to between approximately 3,100 and 4,200 years (or longer, if thermal remediation is unable to achieve the assumed mass reductions). Given the complexities of the Site lithology, area and depth of the DNAPL impacts to soil, and the unique nature of the Montrose DNAPL, there is great uncertainty at this time in any thermal remedy performance estimate. Removal of even 80% to 90% of the DNAPL mass by thermal remediation is considered an optimistic, high-end assumption for mass removal at the Site. At other sites cited by CH2M Hill as precedents, there were pilot studies, extensive modeling, and years of design work. In those cases where a thermal remedy was not abandoned, there was still significant uncertainty associated with implementation of a thermal remedy.

The primary benefit of removing DNAPL mass is to reduce the duration required for hydraulic containment of contaminated groundwater following the groundwater remedy, but based on this evaluation, it will not be technically feasible to remove a sufficient amount of DNAPL to meaningfully reduce the duration of the containment system operation. Furthermore, although some level of uncertainty exists in the selected input parameter values, the sensitivity analysis that H+A conducted bounds the probable range of values, and selected values generally provide low-end estimates of timeframe (H+A, 2009c; Appendix G). Additionally, fine-grained low permeability layers can store significant amounts of dissolved-phase mass which is released very slowly over time (i.e., back diffusion), even after DNAPL in the source zone has been removed. Although the methods used to estimate containment timeframes do not consider back diffusion, the containment timeframes are not expected to be significantly under-estimated since DNAPL dissolution over thousands of years is a more significant driving factor than back diffusion.

It is noted that EPA does not necessarily agree with all of the assumptions used in the containment zone timeframes evaluation as indicated in their comment letter dated December 23, 2008. However, estimating remedy duration is a fundamental requirement for remedy evaluation in the FS, and the methods/assumptions used by H+A in estimating the containment timeframes were reasonable, consistent with industry standards, and have been used at other DNAPL-impacted sites. Responses to EPA comments on the containment timeframes, along with a copy of the updated memorandum, are provided in Appendix G of this FS.

2.6.2 PASSIVE DNAPL ACCUMULATION AND RECOVERY

Wells screened within the DNAPL-impacted portion of the UBA are routinely gauged and purged to remove DNAPL which has passively accumulated in the well sumps. Passive DNAPL recovery in the UBA wells within the CPA has been on-going since 1988 and is summarized in **Appendix F** and presented below:

Passive DNAPL Recovery Since 1988

Well	2008 Passive DNAPL Recovery (gallons)	Cumulative Passive DNAPL Recovery (1988-2008) (gallons)
MW-2	0.0	7.7
UBT-1	4.0	72.4
UBT-2	0.4	19.0
UBT-3	0.0	29.3
UBE-1	3.5	34.3
UBE-2	0.5	0.6
UBE-3	0.0	0.0
UBE-4	38.0	93.3
UBE-5	0.0	0.0
Total	46.4	256.5

Note:
UBE-5 was installed in September 2008 and purged in October 2008

The highest rate and volume of passive DNAPL recovery has occurred within the CPA at the source area wells. Wells UBE-2 and UBE-3 located east of the source areas in the CPA have exhibited either minimal or no passive DNAPL recovery. Passive DNAPL accumulation rates have historically been between approximately 0.001 and 0.02 gallons per day. The passive DNAPL accumulation rate at UBE-4 in 2008 has been approximately 0.1 gallons per day.

Routine passive recovery of DNAPL at a UBA well provides definitive proof of DNAPL presence, because only mobile DNAPL would passively accumulate on a repeated basis. However, the absence of passive DNAPL accumulation is not conclusive evidence that mobile DNAPL is not present; it merely proves that the well has not intercepted mobile DNAPL. In sum, the lack of passive accumulation does not disprove the presence of mobile DNAPL, it only provides information related to DNAPL mobility within near-wellbore conditions.

Mobile DNAPL Occurrence at Well UBE-5

DNAPL characterization data collected in 2003/2004 suggested the presence of mobile DNAPL at boring SSB-12 located southeast of the CPA. A high DNAPL concentration, 105,000 mg/kg, was detected in a soil sample collected at 82.5 feet bgs in boring SSB-12. However, at this eastern location, no mobile DNAPL was expected based on the lack of mobile DNAPL at wells UBE-2 and UBE-3 in the same vicinity and the lack of historical DNAPL sources in this area of the Property. Additionally, the soil samples collected for laboratory analysis in 2004 during the DNAPL Reconnaissance Program were very small in size, only 5 grams. The small discrete sample at boring SSB-12 is an isolated occurrence and the location is remote from known DNAPL source areas. Therefore, to verify the occurrence of mobile DNAPL at this location, well UBE-5 was installed in September 2008 within 5 feet of soil boring SSB-12 as shown in **Figure 2.1**. Well UBE-5 was screened to coincide with the occurrence of DNAPL in that boring (Earth Tech, 2008j).

No mobile DNAPL was found at well UBE-5 after 6 weeks of monitoring for passive accumulation as of mid-October 2008. The well was purged on October 15, 2008 using a bladder pump, confirming that no DNAPL had passively accumulated in the well sump to that point. A short-term extraction test was subsequently conducted at this well in December 2008, during which approximately 1.4 gallons of DNAPL were recovered. A description of the test results is provided in Section 2.6.2.

2.6.3 Hydraulic Displacement Field Pilot Testing

The mobility of DNAPL in the subsurface is a function of its saturation. DNAPL is most mobile at high saturations and its mobility decreases non-linearly as its saturation decreases. If DNAPL is hydraulically displaced from a porous media, a quantity of DNAPL, referred to here as "residual saturation", will remain in the pore spaces as ganglia that have been disconnected from any continuous pool of DNAPL. At residual saturation, the DNAPL is essentially immobile, although its dissolution will remain a source of groundwater contamination over the long-term, thus effectively requiring indefinite containment.

DNAPL has been observed in UBA monitoring and extraction wells located within the CPA. Additionally, since 1988, passive DNAPL accumulation in these wells has been routinely gauged and purged as described in Section 2.5.1. Based on the passive recoverability of the DNAPL, three field-scale hydraulic displacement pilot tests were conducted at the Property in 1991, 2004/2005, and 2008.

The first of these tests was conducted in 1991 at UBA extraction well UBE-1 (**Figure 2.1**; H+A, 1992). A total of 298 gallons of DNAPL was recovered during the 28-day extraction test conducted at this well. The test evaluated only primary pumping mechanisms. While a substantial volume of DNAPL was recovered during the 1991 pilot test, uncertainties remained regarding the potential effectiveness of a hydraulic displacement remedy for DNAPL including: 1) the 28-day test was not conducted for a sufficient period to determine how quickly the DNAPL accumulation rate would decay, and 2) it was unknown if the results obtained at extraction well UBE-1 were typical of what could be expected for overall DNAPL accumulation, or if it represents an unusually productive well.

A second testing program was conducted in 2004 and 2005 to address these uncertainties (H+A, 2007c). Groundwater and DNAPL pumping at extraction well UBE-1 was conducted for a longer duration than the 1991 test in order to assess the amount of time required for the rate of DNAPL accumulation to decay. Additionally, short-duration tests were conducted at four additional wells to determine the variability in DNAPL recovery characteristics across the Property, and water level monitoring was conducted to assess the hydraulic radius of influence at each of the extraction wells. DNAPL recovery observed during the 2004/2005 field pilot test is presented in **Table 2.4** and summarized as follows:

- 398 gallons of DNAPL were recovered from UBE-1 over 109 operating days,
- 45 gallons of DNAPL were recovered from UBT-1 over 18 operating days,
- 11 gallons of DNAPL were recovered from UBE-4 over 19 operating days,
- 0.7 gallons of DNAPL were recovered from UBE-2 over 16 operating days, and
- No DNAPL was recovered from UBE-3 over 14 operating days.

The 2004/2005 testing program provided sufficient data to make the following general conclusions:

1. Timeframes for DNAPL recovery are expected to be considerably shorter at extraction wells located in areas with lower DNAPL saturations, typically near the margin of the CPA. Additionally, no DNAPL recovery is expected in areas where saturations are below the residual saturation.
2. DNAPL recovery varies substantially within the DNAPL-impacted area. DNAPL recovery is tied to the DNAPL saturation in the vicinity of the extraction well.
3. DNAPL recovery is enhanced by creating a groundwater gradient around the extraction well. Overall, the data obtained during the tests indicates that DNAPL recovery rates generally increased as groundwater extraction rates increased.
4. Equipment fouling by DDT and inorganic precipitates will need to be addressed through maintenance during a hydraulic displacement remedy.

A third short-term test was conducted in December 2008 at well UBE-5 located east/southeast of the CPA (Earth Tech, in process). Well UBE-5 was located adjacent to soil boring SSB-12, where a high concentration of DNAPL was measured in soil at one depth of approximately 82.5 feet bgs. The DNAPL concentration observed at this location (103,000 mg/kg) is representative of mobile DNAPL saturations, and therefore, a short-term test was conducted to determine if mobile DNAPL was present within the vicinity of this boring and well. Groundwater was extracted at a rate of approximately 1.0 to 1.75 gpm from UBE, screened from 75 to 85 feet bgs, for a period of approximately 5 days. A total of 8,318 gallons of groundwater was extracted from UBE-5 during this period. During the 4.5 days of extraction, a total of 0.3 gallons of DNAPL were recovered under a drawdown of approximately 15 feet in UBE-5. The pump was lowered into the well screen on the last day, increasing the drawdown to approximately 25 feet, and another 1.2 gallons of DNAPL was recovered in a 5.5-hour period (0.22 gallons per hour or 5.2

gallons per day). A total of approximately 1.5 gallons of DNAPL was recovered from UBE-5 during the short-term test.

To further evaluate hydraulic displacement as a candidate remedial technology for the Site, modeling was conducted, as described in Section 2.6.4, to provide a better estimate of the DNAPL radial distances of capture and the potential for downward migration.

2.6.4 MODELING OF HYDRAULIC DISPLACEMENT ON DNAPL MOBILITY

The performance of a hydraulic displacement DNAPL remedy in the UBA was modeled using the University of Texas Chemical Composition Simulator (UTCHEM), Version 9 (H+A, 2009a and 2009b). DNAPL remediation by hydraulic displacement in the UBA was initially modeled to evaluate both well spacing and timeframes to deplete a DNAPL pool using a hysteresis routine and the van Genuchten capillary pressure-saturation relationship (fit to data that was measured as part of baseline soils analysis for 2-dimensional thermal remediation bench testing; see Section 2.6.5). A simplified model setup was assumed, including one DNAPL-impacted sand layer overlying one low permeability silt layer with one extraction well. Ten simulation runs were conducted by varying five parameters including the hydraulic conductivity of the sand layer, DNAPL pool location, DNAPL pool length, DNAPL saturations, and groundwater drawdown. However, the initial model results predicted spontaneous DNAPL migration laterally within the sand layer under static (non-pumping) conditions due to a lack of heterogeneity within the sand and were therefore considered unreliable. The reason for the spontaneous migration was the use of the van Genuchten capillary pressure-saturation relationship, which does not account for entry pressure.

An alternate modeling approach was used which replaced the van Genuchten capillary pressure-saturation relationship with the Brooks-Corey empirical relationship. The Brooks-Corey relationship accounts for entry pressure but cannot be used with hysteresis in the model. Although this alternate approach does not allow evaluation of pumping durations, it was successfully used to evaluate well spacing and DNAPL capture radius. In lieu of the planned 10 modeling runs, only the most conservative model inputs were assumed to identify the smallest DNAPL capture radius (i.e., use of other model input assumptions would result in larger capture radii). The revised modeling approach, using conservative assumptions, predicted that DNAPL would be effectively mobilized for capture at well spacings up to 120 feet (i.e., 60-foot single well capture radius). The capture radius evaluation was based on an assumed initial DNAPL saturation of 30% and a residual DNAPL saturation of 19%. This model-predicted well spacing (120 feet) was larger than initially expected (less than 50 feet) and suggests that hydraulic displacement may be a more effective DNAPL remedial technology than originally considered by EPA. The initial results of the hydraulic displacement modeling were submitted to EPA in a technical memorandum dated January 15, 2009 (H+A, 2009a). A summary HD modeling report was prepared and submitted to EPA on April 6, 2009 (H+A, 2009b).

A secondary objective of the hydraulic displacement modeling was to evaluate the potential for downward vertical migration into the BFS. Because the silt layers at the Property are laterally discontinuous, DNAPL has the potential to migrate vertically downward to underlying layers as a result of hydraulic displacement. For this reason, a second model setup consisting of five soil layers was assumed to evaluate the potential for downward migration of DNAPL during a hydraulic displacement remedy. Conservative assumptions were used that maximized the amount of DNAPL accumulation over the basal silty sand layer in the UBA, DNAPL pool heights up to 8 feet, thus increasing the potential for DNAPL to overcome the pore entry pressure of that layer and migrate vertically downward. Even under these conservative assumptions, the model predicted that DNAPL would not penetrate through the basal silty sand layer of the UBA and into the underlying BFS. Therefore, the potential for DNAPL downward migration into the underlying BFS as a result of hydraulic displacement appears to be minimal, if any, based on these modeling results.

2.6.5 Soil Vapor Extraction Field Pilot Test

A field pilot test to evaluate the feasibility of removing VOCs from unsaturated soils was conducted at the Property in 2003 (Earth Tech, 2004a). A single SVE well, EW-1, was installed within the CPA between soil borings 14D and S-305/305A, where high concentrations of VOCs were previously reported in soil. The well was constructed with three separate 10-foot screened intervals positioned to coincide with the three unsaturated soil layers at the Property (10-20 feet bgs in the PD, 30-40 feet bgs in the PVS, and 50-60 feet bgs in the unsaturated UBA). Six soil vapor monitoring points, VMP-1 through VMP-6, were installed in varying directions and distances from the extraction well in order to monitor vacuum influence in the subsurface. Short and long-term pilot tests were conducted based on the permeability of the soil matrix (longer tests for low permeability soils). The SVE pilot test provided performance data relative to soil vapor flow rates, soil vapor contaminant concentrations, vacuum or radial influence, and contaminant recovery rates. A summary of SVE field pilot test results is provided below by unsaturated soil layer.

PD

- A vacuum of 18 inches of mercury was required to induce soil vapor flow within the PD, and the flow rate gradually increased over time. Eventually, a soil vapor flow rate of 68 scfm was achieved, although significant vacuum influence within the underlying PVS was observed, indicating that at least a portion of the soil vapor flow was originating from the PVS.
- A relatively low radius of influence of 48 feet was observed during pilot testing.
- MCB concentrations in extracted soil vapors declined from 5,300 to 2,400 ppmv during pilot testing. Chloroform concentrations declined from 1,600 to 1,300 ppmv during pilot testing.
- Based on the pilot test results, an initial VOC mass removal rate of 173 pounds per day was estimated for a well screened in the PD at this location, although a portion of the VOC mass may be originating from the underlying PVS.

PVS

- A relatively high soil vapor flow rate of 111 standard cubic feet per minute (scfm) was observed during pilot testing at an applied well vacuum of 5 inches of mercury.
- A relatively high radius of influence of 123 feet was observed during pilot testing.
- MCB concentrations in extracted soil vapors increased from 4,300 to 5,600 ppmv during pilot testing. Chloroform concentrations increased from 2,100 to 2,200 ppmv.
- Based on the pilot test results, an initial VOC mass removal rate of 472 pounds per day was estimated for a well screened in the PVS at this location.

Unsaturated UBA

- A moderate soil vapor flow rate of 50 scfm was observed during pilot testing at an applied well vacuum of 14 inches of mercury.
- A moderate vacuum radius of influence of 64 feet was observed during pilot testing.
- MCB concentrations in extracted soil vapors declined from 20,000 to 6,800 ppmv during pilot testing. Chloroform concentrations declined from 3,500 to 2,100 ppmv during pilot testing.
- Based on the pilot test results, an initial VOC mass removal rate of 223 pounds per day was estimated for a well screened in the unsaturated UBA at this location.

Granular activated carbon (GAC) was used during the pilot test to treat the extracted soil vapors. The GAC was found to be highly effective in treating the vapor-phase contaminants exhibiting an adsorption capacity of approximately 25% by weight. SVE was found to be a highly effective technology for removing MCB and other VOCs from permeable unsaturated soils within the PVS and unsaturated UBA. However, due to the low permeability of the soils and vertical communication with the underlying PVS, SVE was found to be significantly less effective within the PD.

2.6.6 2-Dimensional Thermal Technology Bench-Scale Studies

Two separate thermal technology bench-scale studies were initiated in March 2008 (Earth Tech, 2008a). The objective of the studies was to evaluate mobilization of the Montrose DNAPL under both steam injection/flushing and electrical resistance heating (ERH). Both studies employed a thin 2-dimensional test cell to simulate in-situ conditions, with approximate dimensions of 3 feet long by 2 feet tall by 6 inches in depth. Soil, groundwater, and DNAPL from the Site were collected to support the studies. To support mass balance calculations, relatively contaminant-free soil and groundwater were collected from boring 2DSB-1 and well MW-3 respectively. The soil core was segregated into three different generalized soil types in order to simulate the layered stratigraphy of the saturated UBA. DNAPL was collected from wells UBE-1 and UBE-4 and was placed into the packed test cell to simulate accumulation above a thin, low permeability capillary barrier. Adequate supplies of all three Site materials were shipped to two different universities for bench-scale testing. The ERH study was conducted by Dr. Bernie Kueper with Queen's University, while the steam injection study was conducted by Dr. Brent Sleep with the University of Toronto. Both university professors are recognized experts in the application of thermal remediation technologies.

Numerous problems were encountered with the ERH test cell when operated under pressure as required by the study workplan, and as a result, efforts to complete the 2-dimensional ERH bench study have been terminated. A summary of this work was submitted to EPA in March 2009 (Queen's University, 2009). Dr. Kueper indicated that the Montrose ERH bench study was "the most challenging laboratory program" he had ever encountered in 20 years of experience conducting laboratory experiments. Problems encountered that might be transferrable to application of ERH at the Montrose Site include:

- Downward leakage of pooled DNAPL along the ERH electrodes or well casings. Given the relatively high electrode and well density typically used during ERH remedies, the potential to intercept pooled DNAPL at the Montrose Site is substantial and would likely pose an increased risk of downward migration;

- Evaluation of materials compatibility for exposure to the Montrose DNAPL. The Viton® gaskets used in the test cell were chemically degraded during the attempted ERH bench study;

- Evaluation of DNAPL wettability against well casings and other materials. Although the Montrose DNAPL was non-wetting to Teflon®, Dr. Kueper found the DNAPL to be slightly wetting to Viton®.

However, 2-dimensional testing using the steam injection cell was successful, and experiment Run 1 was conducted on January 8, 2009. Run 1 results are summarized below:

2-Dimension Steam Flushing Run 1 Results

Run 1 of the 2-dimensional steam flushing experiments was conducted on January 8, 2009. In accordance with the workplan addendum (Earth Tech, 2008a), the soils were packed in the cell as to simulate a higher permeability sand layer overlying a thin, discontinuous, low permeability silt layer or capillary barrier. The test cell soils were saturated with groundwater, and a total of 600 milliliters (ml) or 750 grams of DNAPL from the Site was injected into the sand layer overlying the capillary barrier. Steam was injected into one end of the cell at pressures of 13 to 15 psig and temperatures of 120°C to 132°C for a total duration of approximately 11 hours. Total fluids were recovered from the opposite end of the cell and condensed for measurement and sampling. During this time, the DNAPL-impacted sand layer was heated to the steam temperatures (i.e., 120°C) across the entire length of the cell. Target temperatures were reached within this layer after approximately 6.5 hours of steam injection. A total of 53 pounds of water and steam condensate was recovered during the experiment, which is equivalent to 3.4 pore volumes of steam flushing in the DNAPL-impacted sand layer. The high steam temperatures resulted in desaturation (i.e., boiling of the groundwater) of a portion of the cell during the experiment, specifically the portion surrounding the steam injection well.

A total of 313 grams of DNAPL was recovered during the experiment, representing 42% of the initial mass in place. Approximately 170 ml or 208 grams of DNAPL was recovered during the early portions of the experiment as the steam front initially reached the outlet well, and this DNAPL was found to exhibit a similar composition as the DNAPL initially placed in the cell (approximately 68% MCB and 32% DDT). Another 85 ml or 94 grams of DNAPL was recovered during the remainder of the experiment after the steam front had already reached the outlet well, and analysis of this DNAPL indicated that it was composed of almost entirely MCB (94% MCB and 6% DDT). The dissolved MCB concentration in the water and steam condensate was measured to be 435 mg/L on average, which is consistent with the solubility limit of MCB, representing an additional 11 grams of dissolved-phase constituents.

Following the experiment, the contents of the cell were allowed to cool overnight. The soils in the cell were extensively sampled the following day and analyzed for the presence of MCB and total DDT. Residual MCB concentrations in the former DNAPL-impacted sand layer were found to range from non-detectable to 14,000 mg/kg with an average concentration of 3,100 mg/kg. The highest concentrations were observed directly above the capillary barrier and near the outlet well. Elevated concentrations of total DDT, up to 27,700 mg/kg, were also found in this layer.

MCB and DDT were additionally detected within and below the low permeability capillary barrier. Within the capillary barrier silt layer, MCB and DDT were detected in concentrations up to 1,300 mg/kg and 11,500 mg/kg respectively. In the soils underlying the capillary barrier, MCB and DDT were detected in concentrations up to 3,600 mg/kg and 9,600 mg/kg respectively.

The Run 1 results indicate that only 42% of the original DNAPL mass and 64% of the original MCB mass was removed from the cell by steam injection, even though the sand layer reached target temperature throughout the cell and more than 3 pore volumes of steam (cold water equivalent) was flushed through the sand layer. Post-test analysis of soil in the cell indicated that elevated concentrations of MCB (up to 14,000 mg/kg) remained within the sand layer, and that DNAPL constituents migrated through the capillary barrier (potentially as a result of desaturation) and into soils underlying the capillary barrier.

A memorandum from Dr. Sleep summarizing the results of experiment Run 1 is provided as **Appendix K** (University of Toronto, 2009). Run 2 of the 2-dimensional steam flushing experiments is scheduled to be conducted in April 2009, and results of that run will be reported to EPA under separate cover.

1-Dimensional Steam Flushing Experiments

Dr. Eva Davis of EPA conducted a series of one-dimensional steam flushing column experiments in 2004/2005 using materials collected from the Site in 2003 (Davis, 2006). Soils from four different soil borings (PSB-4, PSB-15, SSB-2, and SSB-6) were used to pack a small one-dimensional test column with dimensions of 2-inches diameter by 6-inches long (i.e., a tubular test cell). Steam was injected in one end of the test column at a temperature of approximately 150°C and a flow rate of approximately 75 ml per hour for a total duration of approximately 5 to 5.5 hours per column. This duration is roughly equivalent to 4 pore volumes of steam flushing. EPA measured the quantity and concentration of total fluids exiting the column, and EPA measured the concentration of contaminants remaining in the steam flushed soil column following treatment. EPA issued a report on the one-dimensional steam flushing column experiments in August 2006 (Davis, 2006).

It is important to be careful in drawing conclusions for full-scale system performance based on one-dimensional column experiments as they do not represent the full range of fluid flow and thermodynamic processes that occur at full-scale. In particular, field-scale thermal technology performance is limited by uneven heat propagation, fluid flow, chemical distribution, and all of these are constrained for optimal performance in one-dimensional column tests. In general, one-dimensional column tests arguably produce better performance results than those achieved at the field-scale for similar operating conditions. Such tests are often good indicators of infeasibility (i.e., identifying conditions that are likely to be unsuccessful), but care must be taken in making any feasibility inferences. Montrose did not request these experiments and believes them to be unreliable in evaluating DNAPL remedial technologies in this FS. Montrose proposed and is in the process of conducting 2-dimensional bench-scale testing of steam flushing in an effort to obtain more reliable bench-scale data for evaluation of this thermal treatment technology.

TABLES

Table 2.1
2008 Field Investigation Results for Presence of DNAPL in BFS Aquifer
Montrose Superfund Site

Sample Identifier	Sample Date	Sample Collection Depth (bgs)	Hydrogeologic Unit	GROUNDWATER SAMPLE RESULTS (micrograms per liter)									FIELD SCREENING RESULTS (a,b)				
				MCB	pCBSA	2,4'-DDD	2,4'-DDE	2,4'-DDT	4,4'-DDD	4,4'-DDE	4,4'-DDT	Total DDT	FLUTEe Ribbon Staining (yes / no)	Visual Evidence	PID (ppm)	FID (ppm)	DNAPL Occurrence
Soil Boring BFSB-1																	
BFSB1-GW-98.5	4/29/2008	98.5	UBA	150,000	720,000	<0.094	<0.094	0.23 (c)	0.11 (c)	0.13	0.33	0.8	no	no	28	34	None
BFSB1-GW-109.5	5/6/2008	109.5	UBA	19,000	33,000	<0.094	<0.094	<0.094	<0.094	<0.094	0.15	0.15	no	no	32	34	None
BFSB1-GW-115	5/6/2008	115	BFS	71,000	87,000	3.4	<0.094	<0.094	3.5	<0.094	0.12	7.02	no	no	21	18	None
BFSB1-GW-120	5/6/2008	120	BFS	90,000	230,000	3.4	<0.094	0.11 (c)	4.9	0.11	0.32	8.84	no	no	59	57	None
BFSB1-GW-125	5/7/2008	125	BFS	96,000	320,000	0.6	<0.094	<0.094	0.54	<0.094	<0.094	1.14	no	no	118	67	None
BFSB100-GW-125 (e)	5/7/2008	125	BFS	100,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	None
Soil Boring BFSB-2																	
BFSB2-GW-100	4/17/2008	100	UBA	13,000	63,000	0.098 (c)	<0.094	<0.094	0.12	<0.094	0.14	0.36	no	no	81	18	None
BFSB2- GW-110	5/1/2008	110	BFS	25,000	52,000	<0.094	<0.094	0.11	0.12	<0.094	0.22	0.45	no	no	4	1	None
BFSB2-GW-114.5	5/2/2008	114.5	BFS	20,000	47,000	<0.094	<0.094	0.13	0.095	0.12 (d)	0.38	0.73	no	no	22	4	None
BFSB2-GW-120	5/2/2008	120	BFS	32,000	97,000	2.8	0.10 (c)	0.28	4.2	<0.094	0.12	7.5	no	no	20.2	0	None
BFSB2-124.5	5/2/2008	124.5	BFS	45,000	130,000	2.3	<0.094	0.28	1.4	0.15	0.5	4.6	no	no	63	69	None

Acronyms/Abbreviations:
bgs = below ground surface
UBA = Upper Bellflower aquitard
BFS = Bellflower sand
MCB = Chlorobenzene
2,4'-DDD = 2,4'-Dichlorodiphenyldichloroethane
2,4'-DDE = 2,4'-Dichlorodiphenyldichloroethylene
2,4'-DDT = 2,4'-Dichlorodiphenyltrichloroethane
4,4'-DDD = 4,4'-Dichlorodiphenyldichloroethane
4,4'-DDE = 4,4'-Dichlorodiphenyldichloroethylene
4,4'-DDT = 4,4'-Dichlorodiphenyltrichloroethane
pCBSA = para-Chlorobenzene sulfonic acid
FLUTe = Flexible Liner Underground Technologies
PID = Photoionization Detector
FID = Flame Ionization Detector
ppm = parts per million
DNAPL = dense non-aqueous phase liquid
(<) = Less than; the numerical value is the Limit of Detection for that compound
NA = Not analyzed

Source : Hargis + Associates, Results of Field Investigation into the Possible Presence of DNAPL in the Bellflower Sand, June 24, 2008.

Footnotes
(a) Results of field screening within the groundwater sampling interval are reported in this table. Refer to lithologic logs (Figures 2 through 4 of above reference) for a complete report of soil screening results in the core intervals.
(b) FID and PID results are provided for the nearest field measurement, if not exactly at the groundwater sample collection depth.
(c) The Relative Percent Difference between the primary and confirmatory analysis exceeded 40%. Per the analytical method, the lower value was reported.
(d) The Relative Percent Difference between the primary and confirmatory analysis exceeded 40%. Per the analytical method, the higher value was reported.
(e) Duplicate sample.

Table 2.2
DNAPL Concentrations in the Saturated UBA (60-105 feet bgs)
Montrose Superfund Site

Soil Boring Identifier	Sample Depth (feet bgs)	Sample Date	Concentrations in milligram per kilogram								
			MCB	2,4'-DDD	2,4'-DDE	2,4'-DDT	4,4'-DDD	4,4'-DDE	4,4'-DDT	Total DDT	Total DNAPL
DP-1	79	5/6/2003	**310**	<51	<51	<51	<51	<51	**110**	**110**	**420**
DP-1	85	5/6/2003	**480**	<71	<71	<71	<71	<71	**170**	**170**	**650**
DP-2	78	5/6/2003	**210**	<27	<27	<27	<27	<27	**42**	**42**	**252**
DP-2	89	5/7/2003	**130**	<29	<29	<29	<29	<29	**110**	**110**	**240**
DP-3	71.5	5/7/2003	<28	<28	<28	<28	<28	<28	<28	<28	0
DP-3	78.8	5/7/2003	**13,000**	<3,700	<3,700	<3,700	<3,700	<3,700	**8,300**	**8,300**	**21,300**
DP-4	76.7	5/8/2003	**30**	<28	<28	<28	<28	<28	<28	<28	**30**
DP-4	86.7	5/8/2003	**45**	<28	<28	<28	<28	<28	<28	<28	**45**
DP-5	72.7	5/8/2003	**95**	<34	<34	<34	<34	**43**	**85**	**128**	**223**
DP-5	89.6	5/8/2003	**3,400**	<1,400	<1,400	<1,400	<1,400	<1,400	**2,400**	**2,400**	**5,800**
DP-7	71.9	5/9/2003	<31	<31	<31	<31	<31	<31	<31	<31	0
DP-7	89.5	5/9/2003	**16,000**	<3,900	<3,900	<3,900	<3,900	<3,900	**12,000**	**12,000**	**28,000**
DP-7	94.9	5/9/2003	**95**	<23	<23	<23	<23	<23	**42**	**42**	**137**
DP-8	79.9	5/12/2003	**100**	<24	<24	<24	<24	<24	<24	<24	**100**
DP-8	89.1	5/12/2003	<27	<27	<27	<27	<27	<27	<27	<27	0
DP-9	75.3	5/13/2003	<22	<22	<22	<22	<22	<22	<22	<22	0
DP-9	85.6	5/13/2003	<30	<30	<30	<30	<30	<30	<30	<30	0
DP-10	72.9	5/13/2003	<30	<30	<30	<30	<30	<30	<30	<30	0
DP-10	85.6	5/13/2003	<26	<26	<26	<26	<26	<26	<26	<26	0
DP-11	76.4	5/14/2003	<28	<28	<28	<28	<28	<28	<28	<28	0
DP-11	81.3	5/14/2003	<27	<27	<27	<27	<27	<27	<27	<27	0
DP-12	72	5/14/2003	**40**	<24	<24	<24	<24	<24	<24	<24	**40**
DP-12	80.4	5/14/2003	**550**	<130	<130	130	<130 J	<130	**420**	**550**	**1,100**
PSB-1	76.5	10/7/2003	**1,700**	<510	<510	<510	<510	<510	**1,900**	**1,900**	**3,600**
PSB-1	81	10/7/2003	**2,400**	<580	<580	620	<580	<580	**2,500**	**3,120**	**5,520**
PSB-2	75	10/8/2003	**7,100**	<1,500	<1,500	2,100	<1,500	<1,500	**7,700**	**9,800**	**16,900**
PSB-2	92	10/8/2003	**43**	<28	<28	<28	<28	<28	<28	<28	**43**
PSB-3	75.5	10/9/2003	**3,000**	<630	<630	650	<630	<630	**2,500**	**3,150**	**6,150**
PSB-3	80	10/9/2003	**480**	<120	<120	<120	<120	<120	**250**	**250**	**730**
PSB-4	75	10/10/2003	**150**	<140	<140	**200**	<140	<140	**680**	**880**	**1,030**
PSB-4	88	10/10/2003	**45,000**	<7,000 J	<7,000 J	9,400 J	<7,000 J	<7,000 J	28,000 J	28,000 J	**45,000**
PSB-4	90.7	10/10/2003	**1,600**	<500	<500	<500	<500	<500	**920**	**920**	**2,520**
PSB-5	91	10/13/2003	**14,000**	<2,900	<2,900	**4,100**	<2,900	<2,900	**12,000**	**16,100**	**30,100**
PSB-6	84.8	10/14/2003	<31	<31	<31	<31	<31	<31	<31	<31	0
PSB-6	90.4	10/14/2003	**27,000**	<6,800	<6,800	**8,100**	<6,800	<6,800	**19,000**	**27,100**	**54,100**
PSB-7	84	10/15/2003	<30 J	<30 J	<30 J	<30 J	<30 J	<30 J	<30 J	<30 J	0
PSB-7	92	10/15/2003	<33 J	<33 J	<33 J	<33 J	<33 J	<33 J	<33 J	<33 J	0
PSB-8	84.5	10/16/2003	<30	<30	<30	<30	<30	<30	<30	<30	0
PSB-9	85.5	10/17/2003	<34	<34	<34	<34	<34	<34	<34	<34	0
PSB-9	92.2	10/17/2003	**2,000**	<280	<280	390	<280	<280	**1,400**	**1,790**	**3,790**
PSB-10	60.5	10/28/2003	<30	<30	<30	<30	<30	<30	<30	<30	0
PSB-10	89.5	10/28/2003	**44**	<33	<33	<33	<33	<33	<33	<33	**44**
PSB-11	74.5	10/29/2003	3,200 J	<2,000 J	<2,000 J	2,300 J	<2,000 J	<2,000 J	6,400 J	6,400 J	0
PSB-11	81.6	10/29/2003	47 J	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	0

Table 2.2
DNAPL Concentrations in the Saturated UBA (60-105 feet bgs)
Montrose Superfund Site

Soil Boring Identifier	Sample Depth (feet bgs)	Sample Date	Concentrations in milligram per kilogram								
			MCB	2,4'-DDD	2,4'-DDE	2,4'-DDT	4,4'-DDD	4,4'-DDE	4,4'-DDT	Total DDT	Total DNAPL
PSB-12	65.2	10/30/2003	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	0
PSB-12	72.8	10/30/2003	670 J	<630 J	<630 J	<630 J	<630 J	<630 J	1,700 J	1,700 J	0
PSB-12	77.4	10/30/2003	1,400 J	<400 J	<400 J	<400 J	<400 J	<400 J	1,100 J	1,100 J	0
PSB-13	68.8	10/31/2003	<51 J	<51 J	<51 J	<51 J	<51 J	<51 J	<51 J	<51 J	0
PSB-13	90	10/31/2003	<47 J	<47 J	<47 J	<47 J	<47 J	<47 J	<47 J	<47 J	0
PSB-14	78.5	11/4/2003	**8,600**	<3,500	<3,500	<3,500	<3,500	<3,500	**9,900**	**9,900**	**18,500**
PSB-14	93.5	11/4/2003	<40	<40	<40	<40	<40	<40	<40	<40	0
PSB-15	75	11/5/2003	9000 J	<2,000 J	<2,000 J	2,600 J	<2,000 J	<2,000 J	8,600 J	8600 J	0
PSB-15	79.75	11/5/2003	**13,000**	<3,300	<3,300	<3,300	<3,300	<3,300	**11,000**	**11,000**	**24,000**
PSB-16	85.25	11/7/2003	<36	<36	<36	<36	<36	<36	<36	<36	0
PSB-16	89.5	11/7/2003	**49**	<35	<35	<35	<35	<35	<35	<35	**49**
PSB-17	88.25	11/10/2003	**9,300**	<2,000	<2,000	2,200	<2,000	<2,000	**10,000**	**10,000**	**19,300**
PSB-17	94	11/10/2003	<34	<34	<34	<34	<34	<34	<34	<34	0
PSB-18	69	11/22/2003	**400**	<400 J	<400 J	510 J	<400 J	<400 J	1,500 J	1,500 J	**400**
PSB-18	88.5	11/22/2003	**5,700**	<1,800 J	<1,800 J	<1,800 J	<1,800 J	<1,800 J	5,900 J	5,900 J	**5,700**
PSB-19	71.8	11/23/2003	<40	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	0
PSB-19	77.2	11/23/2003	**5,200**	<1,500 J	<1,500 J	1,500 J	<1,500 J	<1,500 J	3, 900 J	**3, 900 J**	**5,200**
SSB-1	83	10/20/2003	NA	NA	NA	NA	NA	NA	NA	NA	NA
SSB-1	90.5	10/20/2003	<21	<21	<21	<21	<21	<21	<21	<21	0
SSB-2	56	10/21/2003	<40	<40	<40	<40	<40	<40	<40	<40	0
SSB-2	77	10/21/2003	<30	<30 J	<30 J	<30 J	<30 J	<30 J	<30 J	<30 J	0
SSB-2	87	10/21/2003	**23,000**	<2,900	<2,900	**6,800**	<2,900	<2,900	**19,000**	**25,800**	**48,800**
SSB-3	86	10/22/2003	<40	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	0
SSB-3	90	10/22/2003	<34	<34	<34	<34	<34	<34	<34	<34	0
SSB-5	77.75	10/24/2003	**2,200**	<340	<340	530	<340	<340	1,800	2,330	**4,530**
SSB-5	94.5	10/24/2003	**39**	<33	<33	<33	<33	<33	<33	<33	**39**
SSB-6	77.5	11/6/2003	**15,000**	<3,100	<3,100	<3,100	<3,100	<3,100	**10,000**	**10,000**	**25,000**
SSB-6	88	11/6/2003	<32	<32	<32	<32	<32	<32	<32	<32	0
SSB-6	89.5	11/6/2003	**55,000**	<30,000	<30,000	<30,000	<30,000	<30,000	**35,000**	**35,000**	**90,000**
SSB-6	90.75	11/6/2003	**49,000**	<28,000	<28,000	<28,000	<28,000	<28,000	**29,000**	**29,000**	**78,000**
SSB-7	89.5	11/11/2003	<2,000	<2,000	<2,000	<2,000	<2,000	<2,000	**6,200**	**6,200**	**6,200**
SSB-7	94	11/11/2003	<40	<40	<40	<40	<40	<40	<40	<40	0
SSB-8	82.5	11/12/2003	<40	<40	<40	<40	<40	<40	<40	<40	0
SSB-8	91	11/12/2003	<40	<40	<40	<40	<40	<40	<40	<40	0
SSB-9	72.5	11/14/2003	<45	<45	<45	<45	<45	<45	<45	<45	0
SSB-9	92	11/14/2003	<40	<40	<40	<40	<40	<40	<40	<40	0
SSB-10	82.25	11/18/2003	<40	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	0
SSB-10	88.75	11/18/2003	<34	<34 J	<34 J	<34 J	<34 J	<34 J	<34 J	<34 J	0
SSB-11	78	11/19/2003	**990**	<350 J	<350 J	<350 J	<350 J	<350 J	1,400 J	1,400 J	**990**
SSB-11	92	11/19/2003	**40**	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	**40**
SSB-12	64.9	11/20/2003	<40	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	0
SSB-12	82.5	11/20/2003	**50,000**	<20,000 J	<20,000 J	<20,000 J	<20,000 J	<20,000 J	53,000 J	53,000 J	**50,000**
SSB-13	69.2	11/21/2003	<40	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	0
SSB-13	92	11/21/2003	<40	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	<40 J	0

Table 2.2
DNAPL Concentrations in the Saturated UBA (60-105 feet bgs)
Montrose Superfund Site

Soil Boring Identifier	Sample Depth (feet bgs)	Sample Date	Concentrations in milligram per kilogram								
			MCB	2,4'-DDD	2,4'-DDE	2,4'-DDT	4,4'-DDD	4,4'-DDE	4,4'-DDT	Total DDT	Total DNAPL
SSB-14	79	11/24/2003	<34	<34	<34	<34	<34	<34	<34	<34	0
SSB-14	90.3	11/24/2003	<40	<40	<40	<40	<40	<40	<40	<40	0
SSB-15	78	12/2/2003	<31	<31	<31	<31	<31	<31	<31	<31	0
SSB-15	88	12/2/2003	<34	<34	<34	<34	<34	<34	<34	<34	0
TSB-1	60	11/13/2003	<50	<50	<50	<50	<50	<50	<50	<50	0
TSB-1	71	11/13/2003	<35	<35	<35	<35	<35	<35	<35	<35	0
TSB-2	78.75	11/17/2003	**54**	<36	<36	<36	<36	<36	<36	<36	**54**
TSB-2	87.75	11/17/2003	**28,000**	<4,000	<4,000	**4,700**	<4,000	<4,000	**16,000**	**20,700**	**48,700**
TSB-3	74.7	11/25/2003	<36	<36	<36	<36	<36	<36	<36	<36	0
TSB-3	79.3	11/25/2003	**14,000**	<2,000	<2,000	3,000	<2,000	<2,000	**9,900**	**12,900**	**26,900**
TSB-3	95	11/25/2003	**34**	<32	<32	<32	<32	<32	<32	<32	**34**
TSB-4	72	12/4/2003	<30	<30	<30	<30	<30	<30	<30	<30	0
TSB-4	81.7	12/4/2003	<28	<28	<28	<28	<28	<28	<28	<28	0
TSB-5	81	1/19/2004	**44**	<26	<26	<26	<26	<26	<26	<26	**44**
TSB-5	94.5	1/19/2004	<34	<34	<34	<34	<34	<34	<34	<34	0
TSB-6	80.25	1/20/2004	<36	<36	<36	<36	<36	<36	<36	<36	0
TSB-6	93.75	1/20/2004	<36	<36	<36	<36	<36	<36	<36	<36	0
TSB-7	83.5	1/21/2004	<33	<33	<33	<33	<33	<33	<33	<33	0
TSB-7	91.5	1/21/2004	<34	<34	<34	<34	<34	<34	<34	<34	0
TSB-8	87	1/22/2004	**700**	<200	<200	<200	<200	<200	**460**	**460**	**1,160**
TSB-8	87.1	1/22/2004	**5,100**	<1,700	<1,700	<1,700	<1,700	<1,700	**3,200**	**3,200**	**8,300**
TSB-8	91	1/22/2004	**13,000**	<3,500	<3,500	<3,500	<3,500	<3,500	**8,000**	**8,000**	**21,000**
TSB-9	89	1/23/2004	<35	<35	<35	<35	<35	<35	<35	<35	0
TSB-9	91	1/23/2004	**47**	<35	<35	<35	<35	<35	<35	<35	**47**
TSB-10	77.25	1/26/2004	<31	<31	<31	<31	<31	<31	<31	<31	0
TSB-10	84.5	1/26/2004	**46**	<34	<34	<34	<34	<34	<34	<34	**46**
TSB-11	81	1/27/2004	<34	<34	<34	<34	<34	<34	<34	<34	0
TSB-11	82.5	1/27/2004	**280**	<66	<66	<66	<66	<66	**100**	**100**	**380**
TSB-11	91	1/27/2004	<50	<50	<50	<50	<50	<50	<50	<50	0
TSB-12	85.5	1/28/2004	<40	<40	<40	<40	<40	<40	<40	<40	0
TSB-12	94.75	1/28/2004	<40	<40	<40	<40	<40	<40	<40	<40	0
TSB-13	69	1/29/2004	<33	<33	<33	<33	<33	<33	<33	<33	0
TSB-13	95	1/29/2004	**45**	<40	<40	<40	<40	<40	<40	<40	**45**
TSB-14	88	2/2/2004	**35**	<35	<35	<35	<35	<35	<35	<35	**35**
TSB-14	92.5	2/2/2004	**40**	<30	<30	<30	<30	<30	<30	<30	**40**
TSB-15	82	2/4/2004	<34	<34	<34	<34	<34	<34	<34	<34	0
TSB-15	88	2/4/2004	<35	<35	<35	<35	<35	<35	<35	<35	0
TSB-15	92	2/4/2004	<35	<35	<35	<35	<35	<35	<35	<35	0
TSB-16	83	8/29/2004	<35	<35	<35	<35	<35	<35	<35	<35	0
TSB-16	90	8/29/2004	<40	<40	<40	<40	<40	<40	<40	<40	0
C59-67	67	5/16/2005	<40	<40	<40	<40	<40	<40	<40	<40	0
C59-84	84	5/16/2005	**66**	<30	<30	<30	<30	<30	<30	<30	**66**
C42-81	81	5/17/2008	<35	<35	<35	<35	<35	<35	<35	<35	0
C42-88	88	5/17/2008	<23	<23	<23	<23	<23	<23	<23	<23	0

Table 2.2
DNAPL Concentrations in the Saturated UBA (60-105 feet bgs)
Montrose Superfund Site

Soil Boring Identifier	Sample Depth (feet bgs)	Sample Date	Concentrations in milligram per kilogram								
			MCB	2,4'-DDD	2,4'-DDE	2,4'-DDT	4,4'-DDD	4,4'-DDE	4,4'-DDT	Total DDT	Total DNAPL
C13-77	77	5/18/2005	<30	<30	<30	<30	<30	<30	<30	<30	0
C13-86	86	5/18/2005	<29	<29	<29	<29	<29	<29	<29	<29	0
C44-76.7	76.7	5/19/2005	**62**	<32	<32	<32	<32	<32	<32	<32	**62**
C44-81	81	5/19/2005	**4,100**	<760	<760	**960**	<760	<760	**2,900**	**3,860**	**7,960**
C30-66.5	66.5	5/20/2005	**8,300**	<1,600	<1,600	**1,600**	<1,600	<1,600	**5,000**	**6,600**	**14,900**
C30-85	85	5/20/2005	**120**	<110	<110	**150**	<110	<110	**650**	**800**	**920**

Footnotes:

bgs = Below ground surface

J = Estimated value

2,4'-DDD = 2,4'-Dichlorodiphenyldichloroethane

2,4'-DDE = 2,4'-Dichlorodiphenyldichloroethylene

2,4'-DDT = 2,4'-Dichlorodiphenyltrichloroethane

4,4'-DDD = 4,4'-Dichlorodiphenyldichloroethane

4,4'-DDE = 4,4'-Dichlorodiphenyldichloroethylene

4,4'-DDT = 4,4'-Dichlorodiphenyltrichloroethane

(<) = Less than the Laboratory Reporting Limit

MCB = Monochlorobenzene

Total DDT = Sum of 2,4' and 4,4' isomers of DDT, DDD, DDE

Total DNAPL= Sum of MCB and Total DDT

Source:

Hargis + Associates, Results of DNAPL Reconnaissance Investigation, October 22, 2004.

Table 2.3
DNAPL Thickness in Saturated UBA (60-105 feet bgs)
Montrose Superfund Site

Boring ID	Saturated UBA			
	Maximum MCB Concentration (mg/kg)	Maximum Total DDT Concentration (mg/kg)	Maximum DNAPL Concentration (mg/kg)	Liberal DNAPL Thickness (feet)
DP- 1	480	170	650	0.50
DP- 2	210	110	320	0.00
DP- 3	13,000	8,300	21,300	0.50
DP- 4	45	<28	45	0.00
DP- 5	3,400	2,400	5,800	0.30
DP- 7	16,000	12,000	28,000	1.00
DP- 8	100	<24	100	0.00
DP- 9	<30	<30	<60	0.00
DP- 10	<30	<30	<60	0.00
DP- 11	<28	<28	<56	0.00
DP- 12	550	550	1,100	1.25
PSB- 1	2,400	3,120	5,520	2.50
PSB- 2	7,100	9,800	16,900	0.85
PSB- 3	3,000	3,150	6,150	1.75
PSB- 4	45,000	37,400	82,400	2.95
PSB- 5	14,000	16,100	30,100	2.50
PSB- 6	27,000	27,100	54,100	0.35
PSB- 7	<33	<33	<66	0.00
PSB- 8	<30	<30	<60	0.00
PSB- 9	2,000	1,790	3,790	4.00
PSB- 10	44	<33	44	0.00
PSB- 11	3,200	8,700	11,900	2.00
PSB- 12	1,400	1,100	2,500	1.55
PSB- 13	<51	<51	<102	0.00
PSB- 14	8,600	9,900	18,500	1.00
PSB- 15	13,000	11,000	24,000	1.75
PSB- 16	49	<35	49	0.00
PSB- 17	9,300	12,200	21,500	1.00
PSB- 18	5,700	5,900	11,600	1.75
PSB- 19	5,200	5,400	10,600	0.25
SSB- 1	<21	<21	<42	0.00
SSB- 2	23,000	25,800	48,800	2.35
SSB- 3	<40	<40	<80	0.00
SSB- 4	N/A	N/A	N/A	0.00

Table 2.3
DNAPL Thickness in Saturated UBA (60-105 feet bgs)
Montrose Superfund Site

Boring ID	Saturated UBA			
	Maximum MCB Concentration (mg/kg)	Maximum Total DDT Concentration (mg/kg)	Maximum DNAPL Concentration (mg/kg)	Liberal DNAPL Thickness (feet)
SSB- 5	2,200	2,330	4,530	0.95
SSB- 6	55,000	35,000	90,000	2.50
SSB- 7	<2,000	6,200	6,200	1.50
SSB- 8	<40	<40	<80	0.00
SSB- 9	<45	<45	<90	0.00
SSB- 10	<40	<40	<80	0.00
SSB- 11	990	1,400	2,390	0.70
SSB- 12	50,000	53,000	103,000	1.00
SSB- 13	<40	<40	<80	0.00
SSB- 14	<40	<40	<80	0.00
SSB- 15	<34	<34	<68	0.00
TSB- 1	<50	<50	<100	0.00
TSB- 2	28,000	20,700	48,700	0.30
TSB- 3	14,000	12,900	26,900	1.60
TSB- 4	<30	<30	<60	0.00
TSB- 5	44	<34	44	0.00
TSB- 6	<36	<36	<72	0.00
TSB- 7	<34	<34	<68	0.00
TSB- 8	13,000	8,000	21,000	0.95
TSB- 9	47	<35	47	0.00
TSB- 10	46	<34	46	0.00
TSB- 11	280	100	380	0.00
TSB- 12	<40	<40	<80	0.00
TSB- 13	45	<40	45	0.00
TSB- 14	40	<35	40	0.00
TSB- 15	<35	<35	<70	0.00
TSB- 16	<40	<40	<80	0.00
C- 13	<30	<30	<60	0.00
C- 30	8,300	6,600	14,900	2.00
C- 42	<35	<35	<70	0.00
C- 44	4,100	3,860	7,960	1.00
C- 59	66	<40	66	0.00
S- 101/101A	36,000	51,000	87,000	1.05
S- 201	N/A	N/A	N/A	N/A

Table 2.3
DNAPL Thickness in Saturated UBA (60-105 feet bgs)
Montrose Superfund Site

Boring ID	Saturated UBA			
	Maximum MCB Concentration (mg/kg)	Maximum Total DDT Concentration (mg/kg)	Maximum DNAPL Concentration (mg/kg)	Liberal DNAPL Thickness (feet)
S- 202	N/A	N/A	N/A	N/A
S- 203	N/A	N/A	N/A	N/A
S- 204	N/A	N/A	N/A	N/A
S- 301/301A	12,000	3,800	15,800	1.20
S- 302A	54	88	142	1.45
S-302E/302F	N/A	N/A	N/A	1.45
S- 303/303A	1	8	9	0.00
S- 304/304A	4,900	69,000	73,900	1.00
S- 305/305A	81,000	24,000	105,000	2.20
MW- 2	7,400	4,980	12,380	N/A
UBT- 1	N/A	N/A	N/A	14.15
UBT- 2	N/A	N/A	N/A	7.55
UBT- 3	N/A	N/A	N/A	4.50
LW- 1	N/A	N/A	N/A	1.30

Notes:

DNAPL = Dense Non Aqueous Phase Liquid

MCB = Monochlorobenzene

UBA = Upper Bellflower Aquitard

DDT= Dichlorodiphenyltrichloroethane

Total DDT = Sum of 2,4' and 4,4' isomers of DDT, DDD, DDE

mg/kg= milligrams per kilogram

bgs = Below ground surface

N/A = Not Available

Sources:

Earth Tech, DNAPL Focused Treatment Area Evaluation, Saturated UBA, June 5, 2008.

Hargis + Associates, Evaluation of Containment Zone Timeframes Following a DNAPL Remedy at the Montrose Site, September 4, 2008

Table 2.4
Hydraulic Displacement Field Pilot Test Results
Montrose Superfund Site

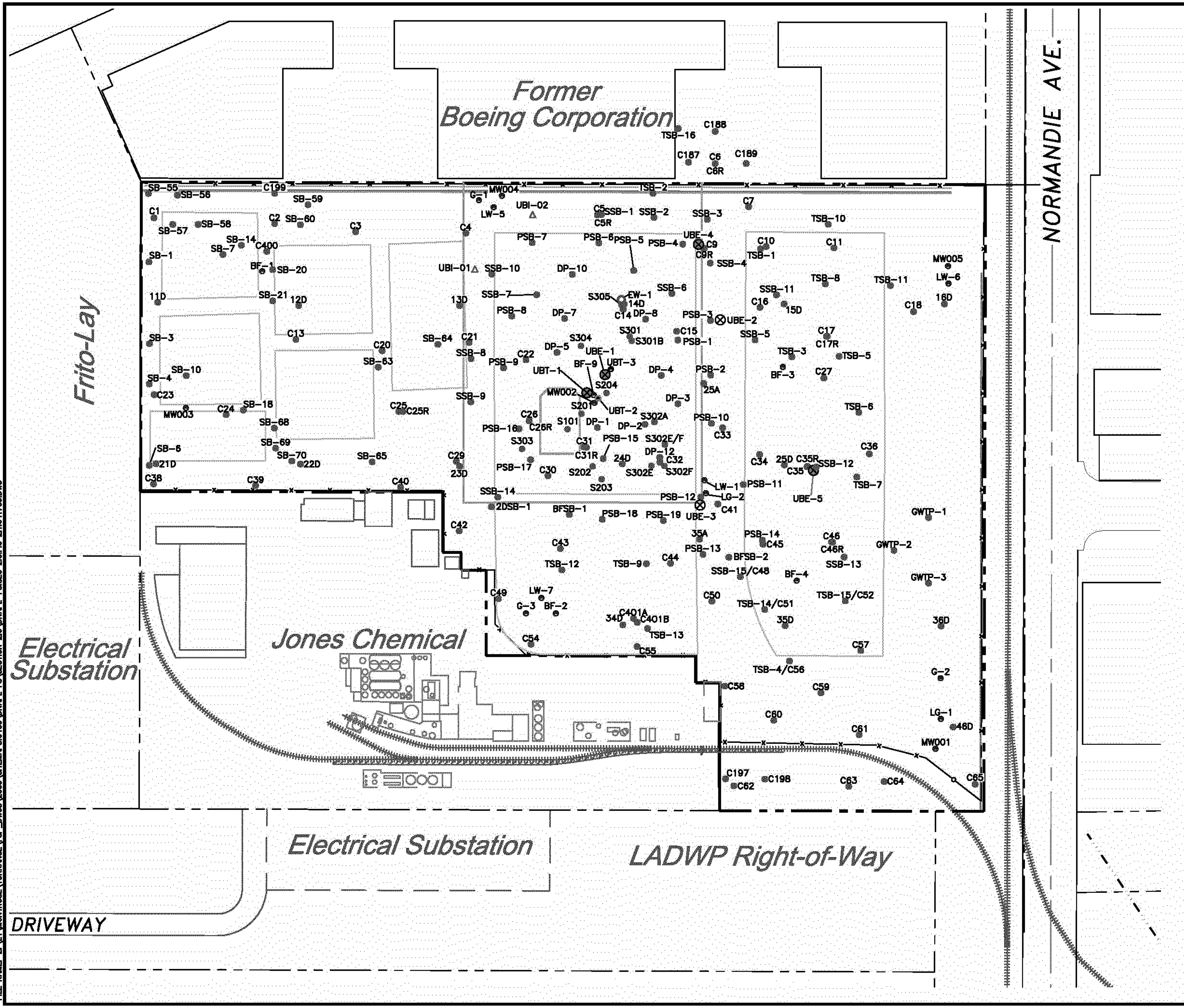
EXTRACTION WELL	CUMMULATIVE GW EXTRACTION RATE (gpm)	GW DRAWDOWN (feet)	DNAPL RECOVERED (liters)	DNAPL RECOVERED (gallons)	TOTAL DURATION[1]			OPERATING DURATION[1]		
					DURATION (hours)	DNAPL RECOVERY RATE (gph)	DNAPL SPECIFIC CAPACITY (gph/ft)	DURATION (hours)	DNAPL RECOVERY RATE (gph)	DNAPL SPECIFIC CAPACITY (gph/ft)
Active groundwater extraction in the indicated well:										
1991 28-day Test										
UBE-1	7.0	10.0	1,084.9	286.4	672	0.43	0.04	671	0.43	0.04
2004/2005 Tests										
UBE-1	2.4	1.3	40.8	10.8	667	0.02	0.01	484	0.02	0.02
	5.2	2.9	259.7	68.6	1,199	0.06	0.02	483	0.14	0.05
	8.5	5.0	671.2	177.2	2,856	0.06	0.01	1,289	0.14	0.03
	11.8	7.4	536.5	141.6	456	0.31	0.04	371	0.38	0.05
	Subtotals		**1,508.2**	**398.2**	**5,178**			**2,627**		
UBE-2	1.9	4.7	2.5	0.7	308	.002 (intermittent)	4.0×10^{-4}	136	0.005 (intermittent)	0.001
	2.6	7.1	0.0	0.0	218	no recovery	no recovery	240	no recovery	no recovery
	Subtotals		**2.5**	**0.7**	**526**			**376**		
UBE-3	4.1	7.2	0.0	0.0	211	no recovery	no recovery	182	no recovery	no recovery
	8.0	16.6	0.0	0.0	263	no recovery	no recovery	160	no recovery	no recovery
	Subtotals		0.0	0.0	**474**			**342**		
UBE-4	7.5	5.9	0.0	0.0	58	no recovery	no recovery	51	no recovery	no recovery
	9.9	7.9	5.0	1.3	95	0.01	0.002	55	0.02	0.003
	11.2	9.0	38.0	10.0	479	0.02	0.002	347	0.03	0.003
	Subtotals		**43**	**11.4**	**632**			**453**		
UBT-1	6.0	7.4	2.1	0.6	49	0.01	0.002	24	0.02	0.003
	8.1	11.9	112.7	29.8	314	0.09	0.008	290	0.10	0.009
	9.6	16.3	56.2	14.8	194	0.08	0.005	112	0.13	0.008
	Subtotals		**171**	**45.1**	**557**			**426**		
2008 Test										
UBE-5	1.4[2]	15.2	1.25	0.3	143	0.002	0.0002	128.0	0.003	0.0002
	1.5[3]	25.5	4.5	1.2	5.5	0.2	0.009	5.5	0.2	0.008
	Subtotals		**5.8**	**1.5**	**148.5**			**133.5**		

Notes:
1. "Total Duration" represents the entire period associated with a particular rate step even if the pumps were not operating.
"Operating Duration" represents only the cummulative operating time associated with a particular rate step.
2. Grundfos Pump set above screen at 74' bgs
3. Grundfos Pump set in middle of the screen at 85' bgs

Abbreviations:
DNAPL = Dense non-aqueous phase liquid
GW = Groundwater
gpm = Gallons per minute
gph = Gallons per hour
gph/ft = Gallons per hour per foot of groundwater drawdown

Source:
Hargis + Associates, DNAPL Extraction Test Summary Report, June 4, 2008.
Earth Tech, Technical Memorandum Re: DNAPL Extraction Test at UBE-5, In Process

FIGURES



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Extraction Well

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

NORTH

0 60 120 FEET

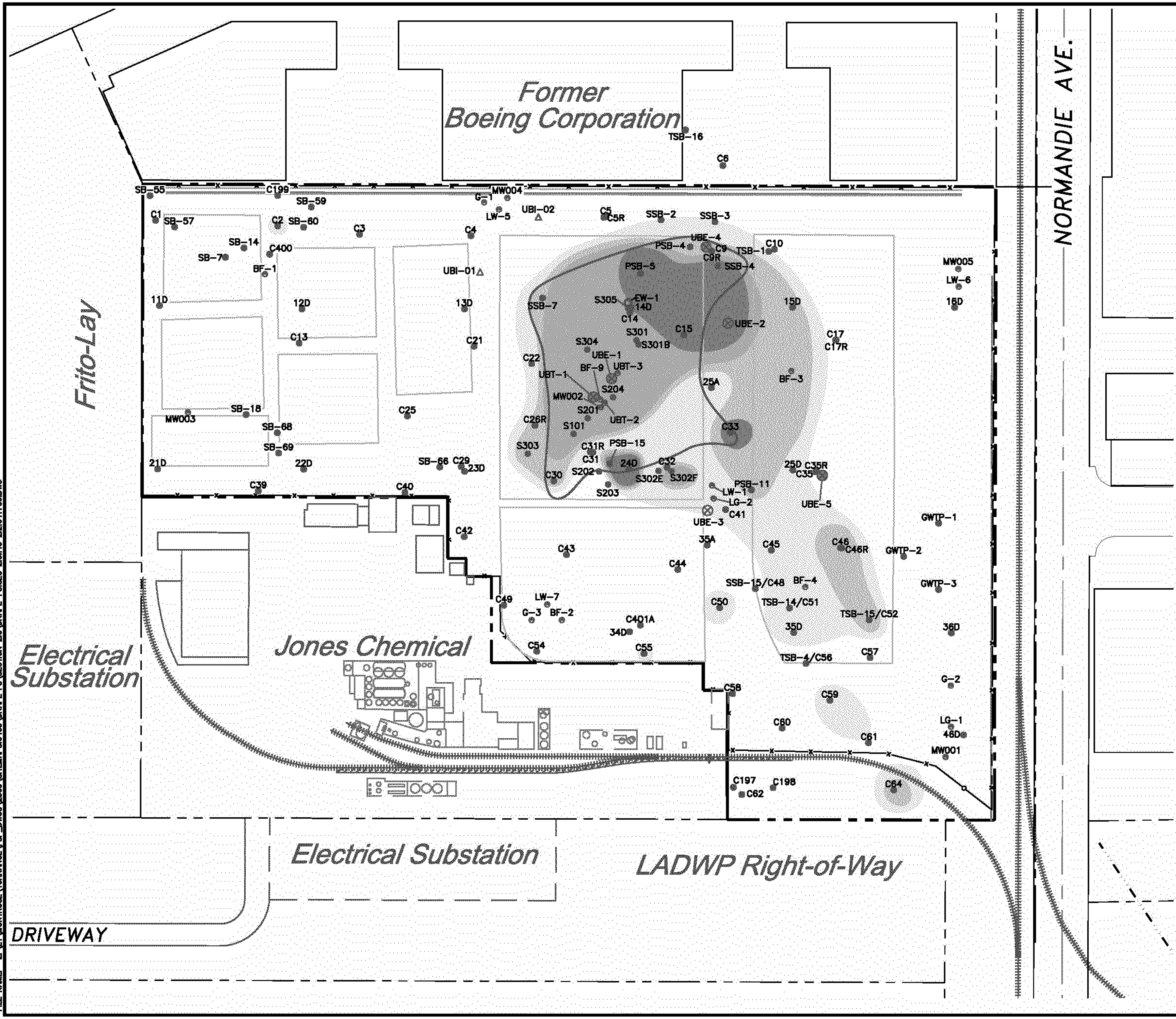
SCALE: 1" = 120'

Montrose Chemical Corporation

On Site Soil Boring/ Well Location Map

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.1

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2008\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.1.041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Maximum MCB Isoconcentration in Soil Contour Interval 10–100 mg/kg
- Average Maximum MCB Isoconcentration in Soil Contour Interval 100–1000 mg/kg
- Average Maximum MCB Isoconcentration in Soil Contour Interval 1000–10,000 mg/kg
- Average Maximum MCB Isoconcentration in Soil Contour Interval >10,000 mg/kg

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

NORTH

0 60 120 FEET

SCALE: 1" = 120'

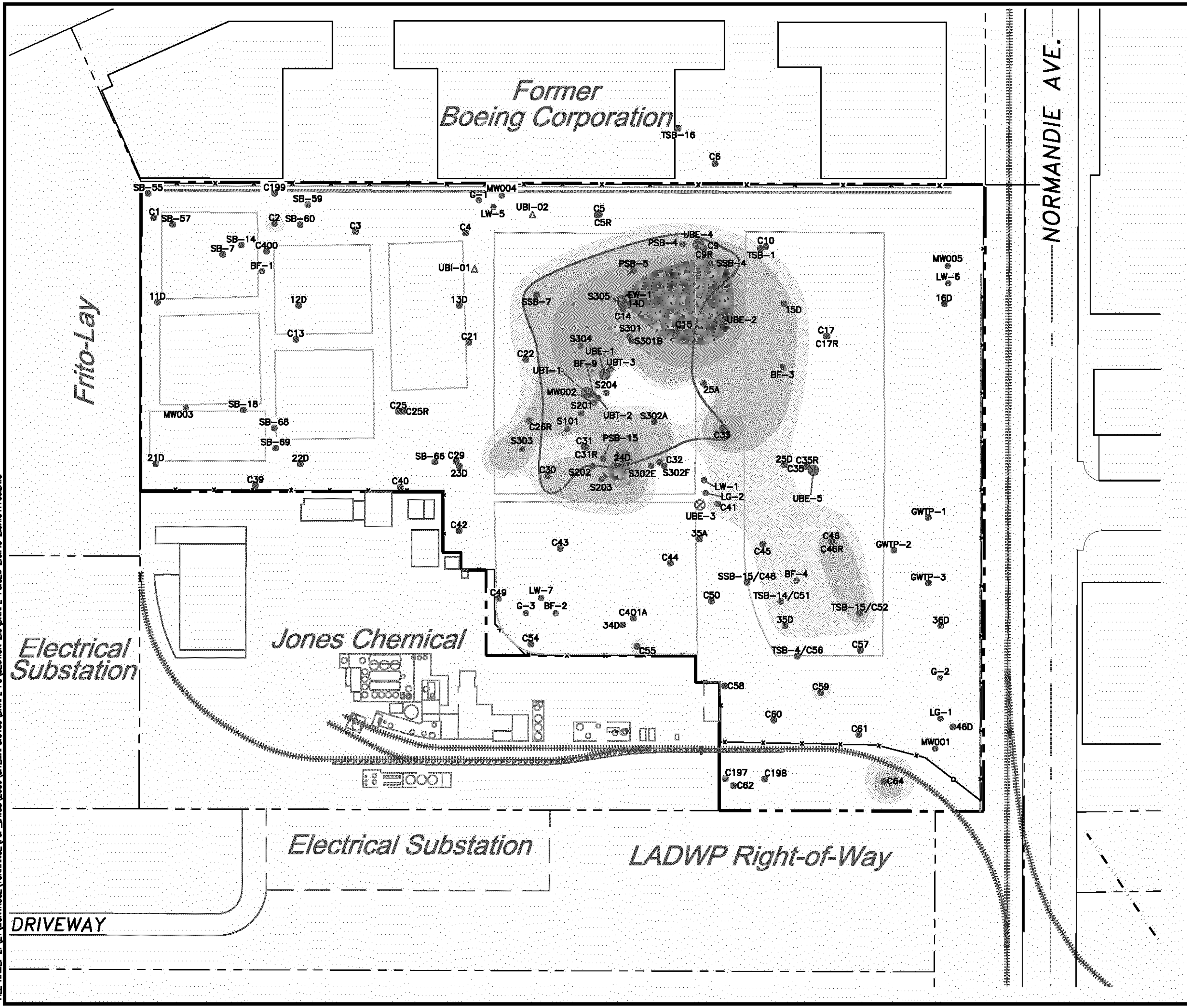
Montrose Chemical Corporation

Maximum MCB Concentration in the Unsaturated Zone (0-60 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.2

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.2.041709.DWG

BOE-C6-0059674



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Maximum MCB Isoconcentration in Soil Contour Interval 10–100 mg/kg
- Average Maximum MCB Isoconcentration in Soil Contour Interval 100–1000 mg/kg
- Average Maximum MCB Isoconcentration in Soil Contour Interval 1000–10,000 mg/kg
- Average Maximum MCB Isoconcentration in Soil Contour Interval >10,000 mg/kg

References:

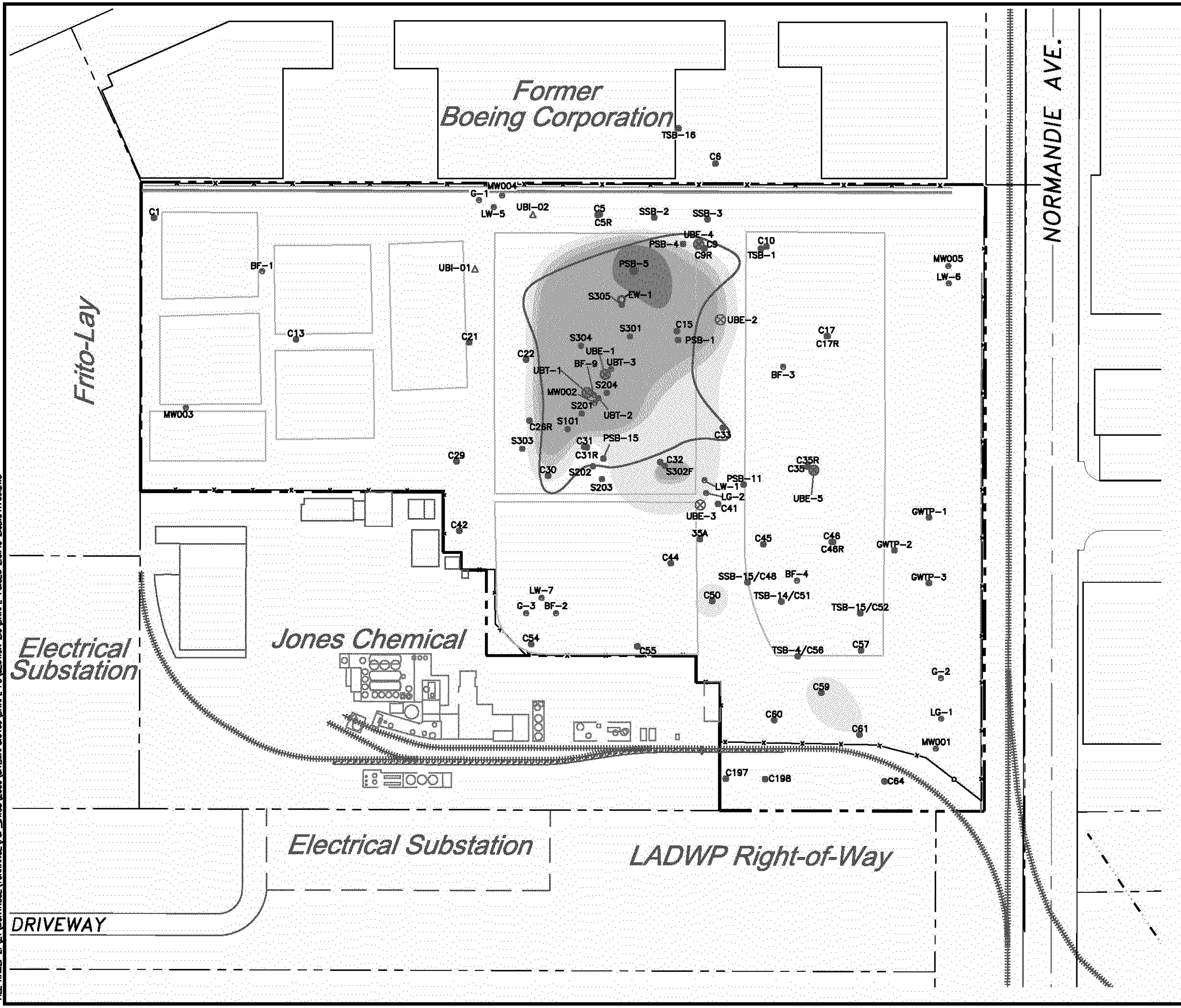
1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

Montrose Chemical Corporation

Maximum MCB Concentration in the Unsaturated Zone (0-25 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	2.3a

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FS_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.3A.041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Maximum MCB Isoconcentration in Soil Contour Interval 10–100 mg/kg
- Average Maximum MCB Isoconcentration in Soil Contour Interval 100–1000 mg/kg
- Average Maximum MCB Isoconcentration in Soil Contour Interval 1000–10,000 mg/kg
- Average Maximum MCB Isoconcentration in Soil Contour Interval >10,000 mg/kg

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

NORTH

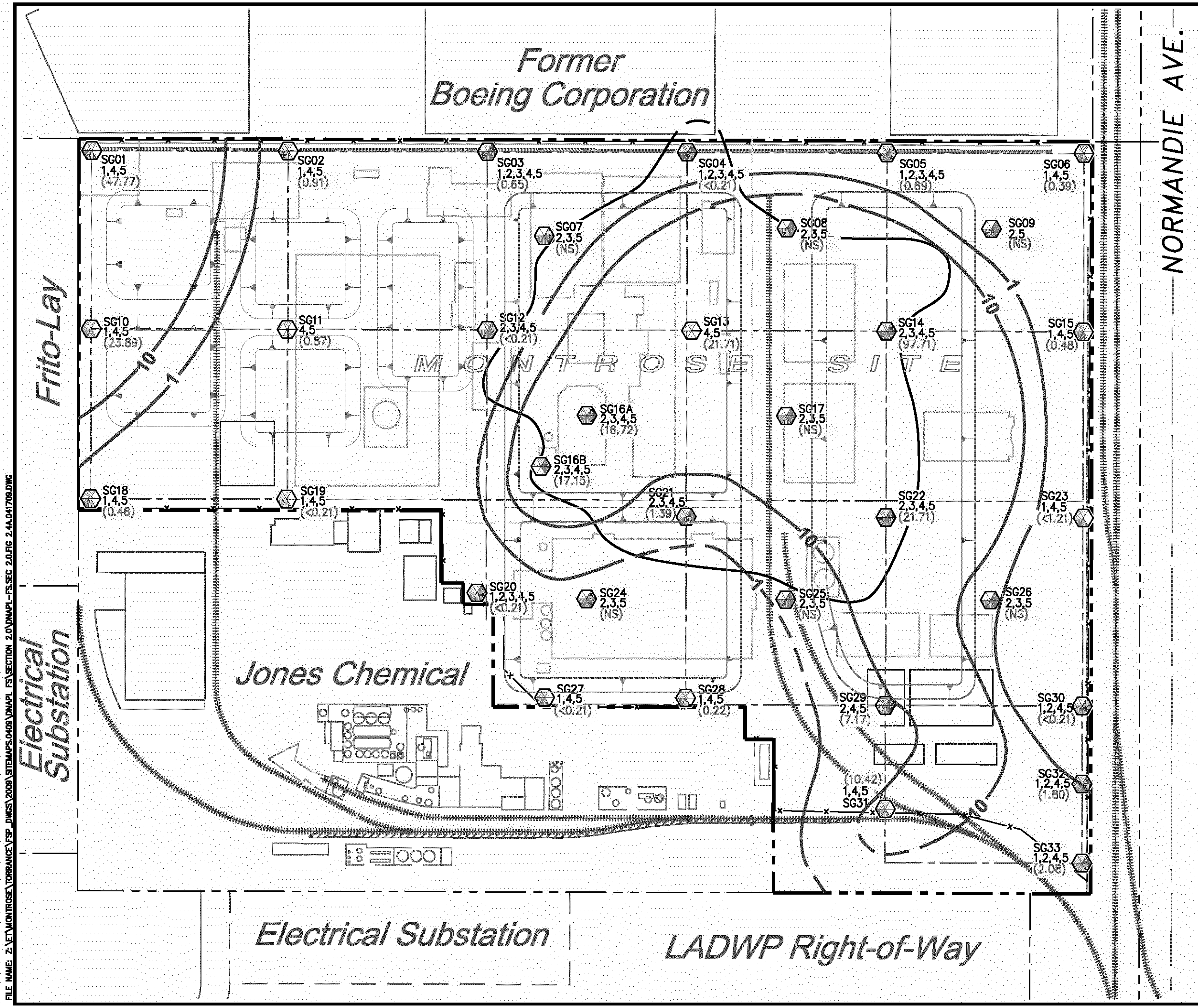
0 60 120 FEET

SCALE: 1"= 120'

Montrose Chemical Corporation		
Maximum MCB Concentration in the Unsaturated Zone (25-60 Feet bgs)		
Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	2.3b

FILE NAME: Z:\ET_MONTROSE\TORRANCE\FS_DWGS\2009\STEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.3B.041709.DWG

BOE-C6-0059676



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — MCB Concentrations Reported in ppmv at 5-Feet Below Grade Surface (BGS)
- 10 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

References:

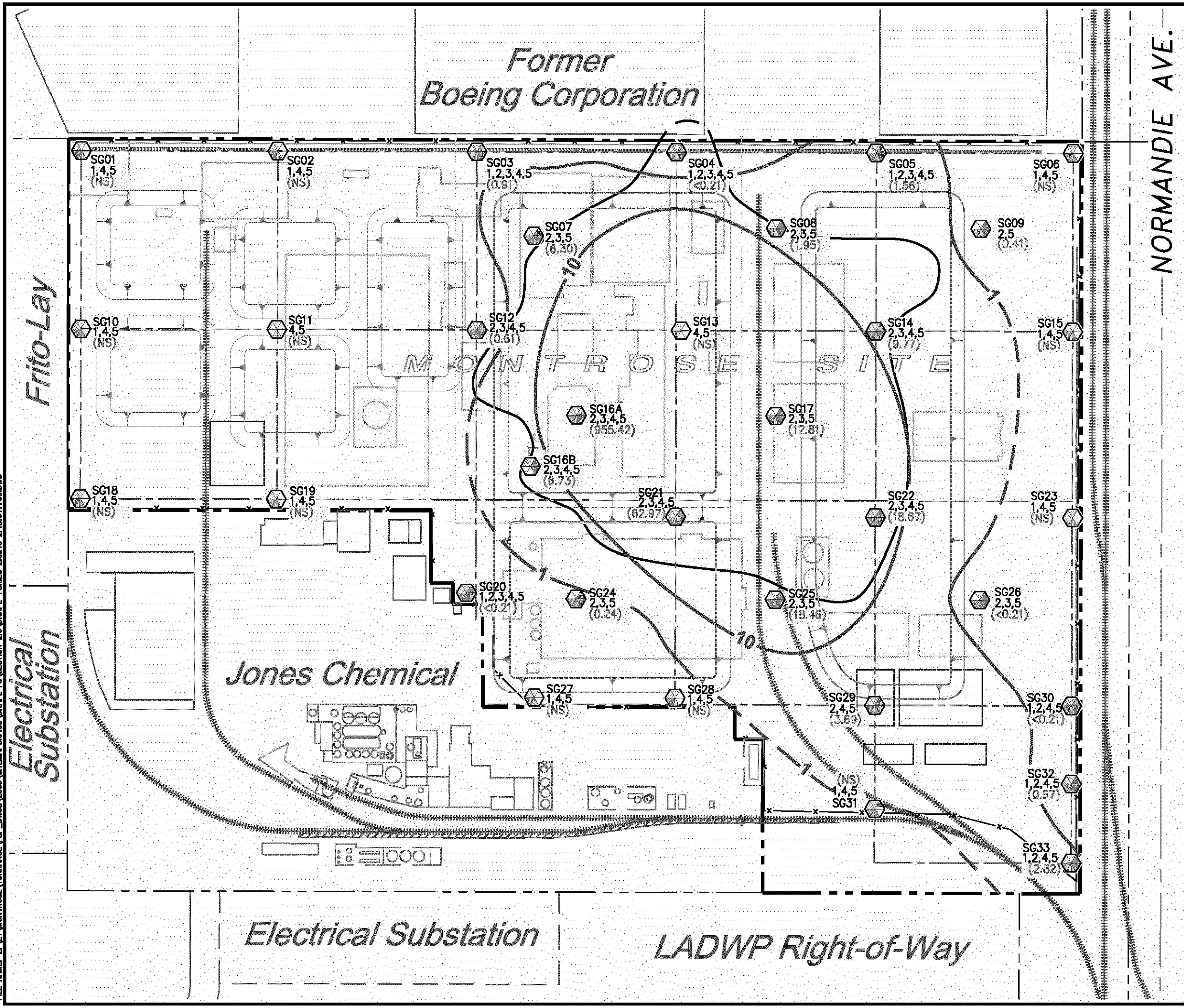
1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

Montrose Chemical Corporation

MCB in Soil Gas
(5 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.4a

BOE-C6-0059677



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — MCB Concentrations Reported in ppmv at 15-Feet Below Grade Surface (BGS)
- 10 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

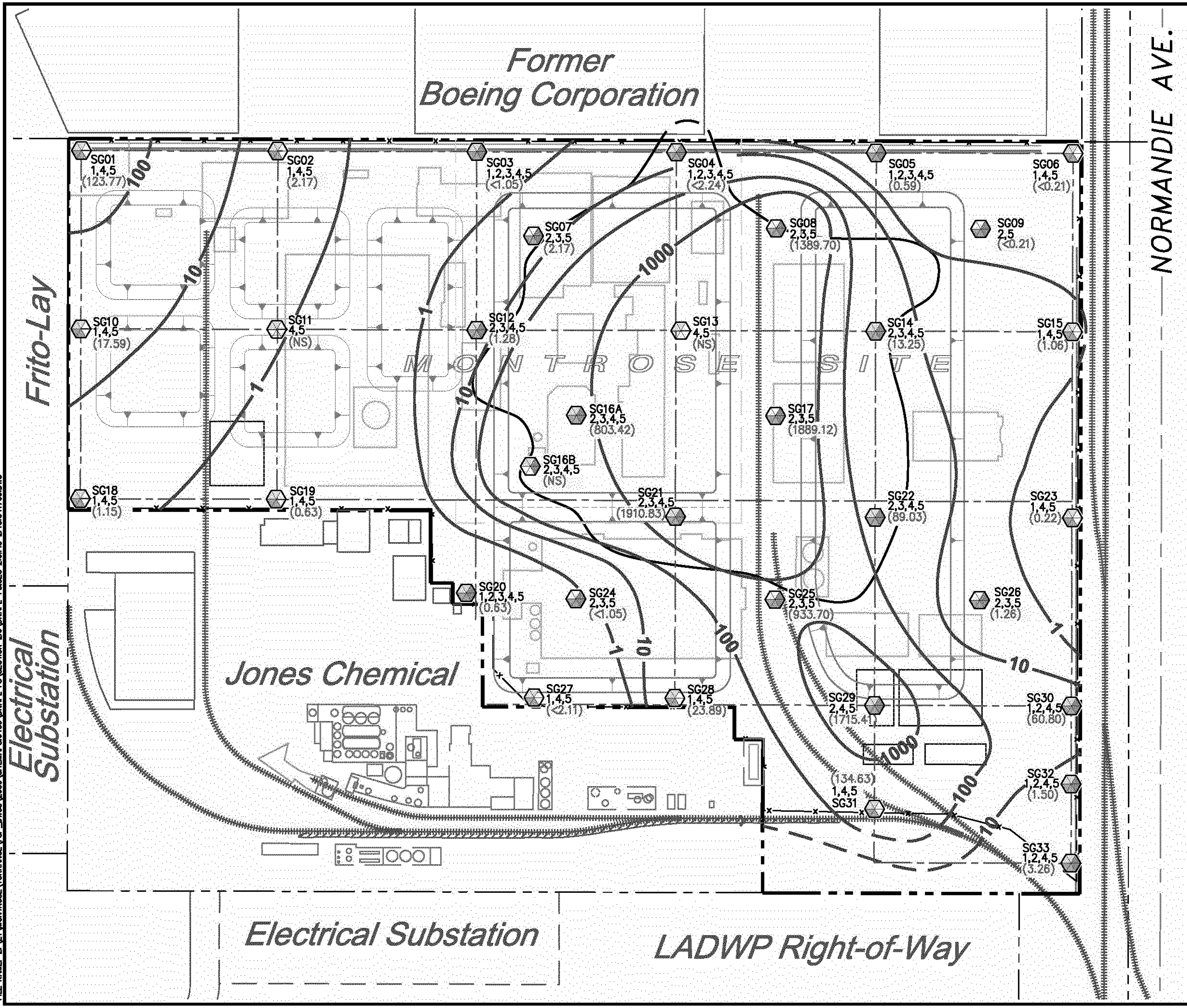
References:

1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

Montrose Chemical Corporation

MCB in Soil Gas
(15 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure 2.4b
Project No. 103649	EARTH TECH AECOM	



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — MCB Concentrations Reported in ppmv at 35-Feet Below Grade Surface (BGS)
- 10 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

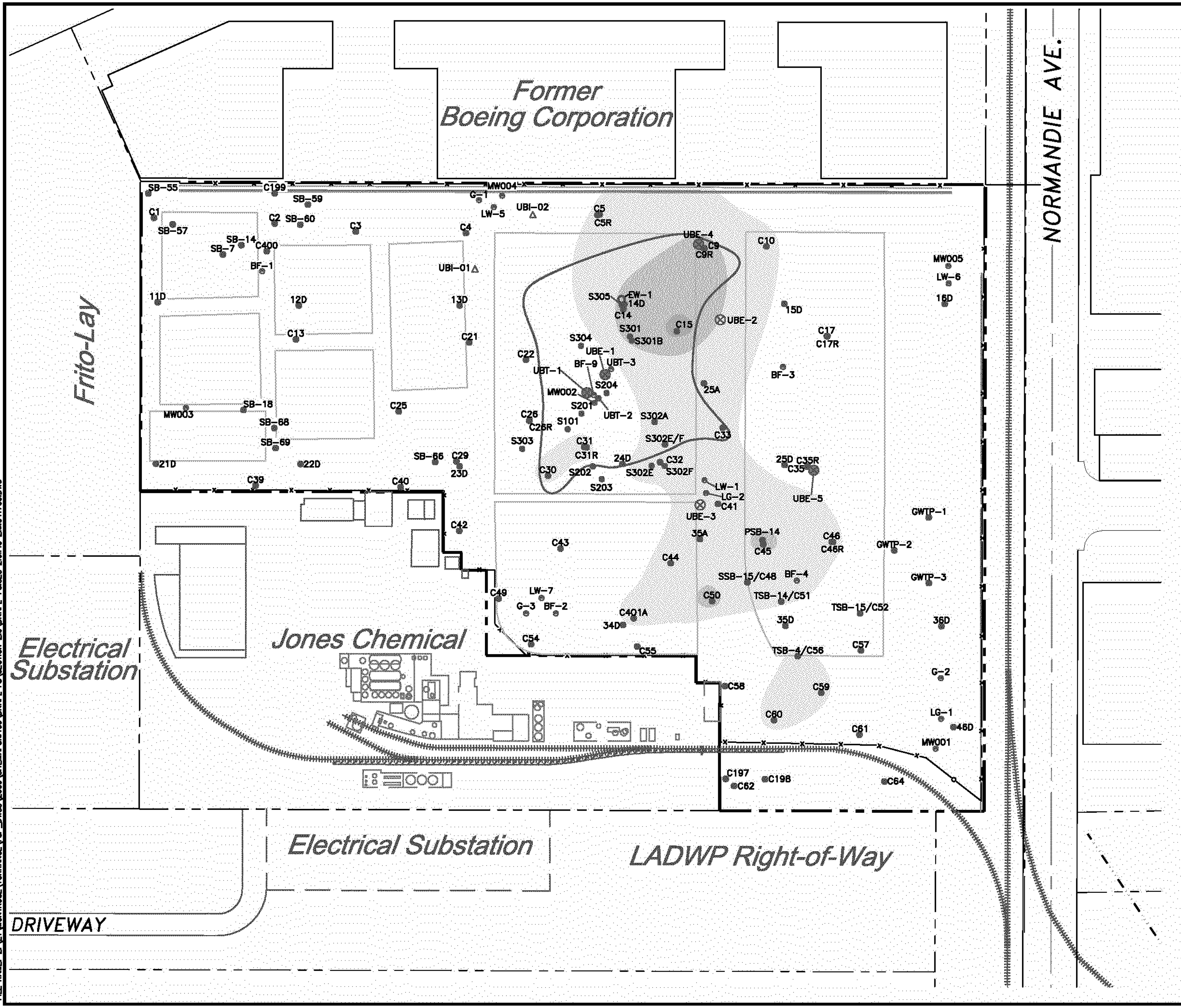
References:

1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004. Continental Aerial, circa 1962. Continental Aerial, circa 1981. TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

Montrose Chemical Corporation

MCB in Soil Gas
(35 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.4c



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Maximum Chloroform Isoconcentration in Soil Contour Interval 1–10 mg/kg
- Average Maximum Chloroform Isoconcentration in Soil Contour Interval 10–100 mg/kg
- Average Maximum Chloroform Isoconcentration in Soil Contour Interval 100–1,000 mg/kg

2008 EPA Industrial PRG = 1.5 mg/kg

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

NORTH

0 60 120 FEET

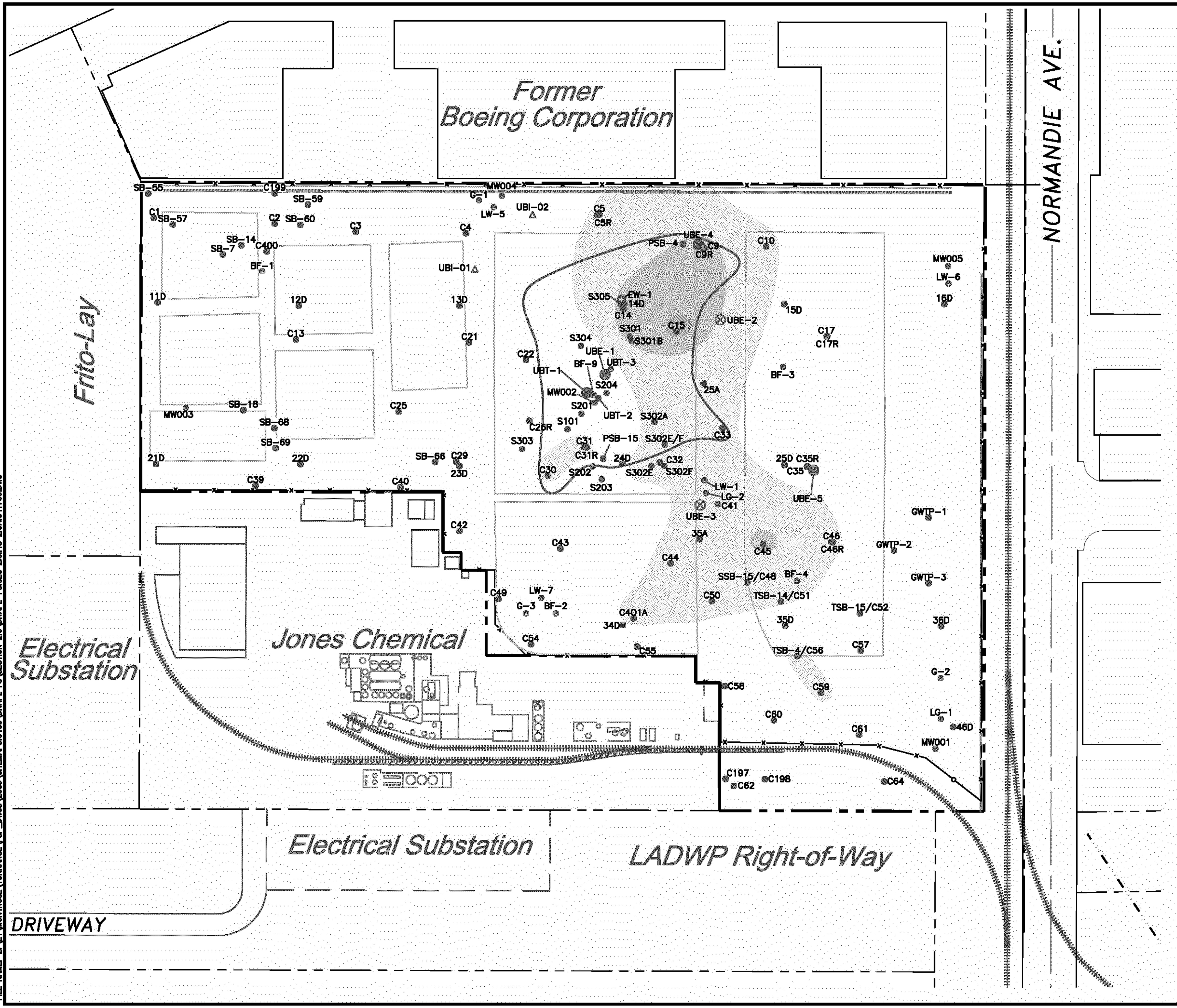
SCALE: 1"= 120'

Montrose Chemical Corporation

Maximum Chloroform Concentration in the Unsaturated Zone (0-60 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	2.5

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.5.041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Maximum Chloroform Isoconcentration in Soil Contour Interval 1–10 mg/kg
- Average Maximum Chloroform Isoconcentration in Soil Contour Interval 10–100 mg/kg
- Average Maximum Chloroform Isoconcentration in Soil Contour Interval 100–1,000 mg/kg

2008 EPA Industrial PRG = 1.5 mg/kg

References:

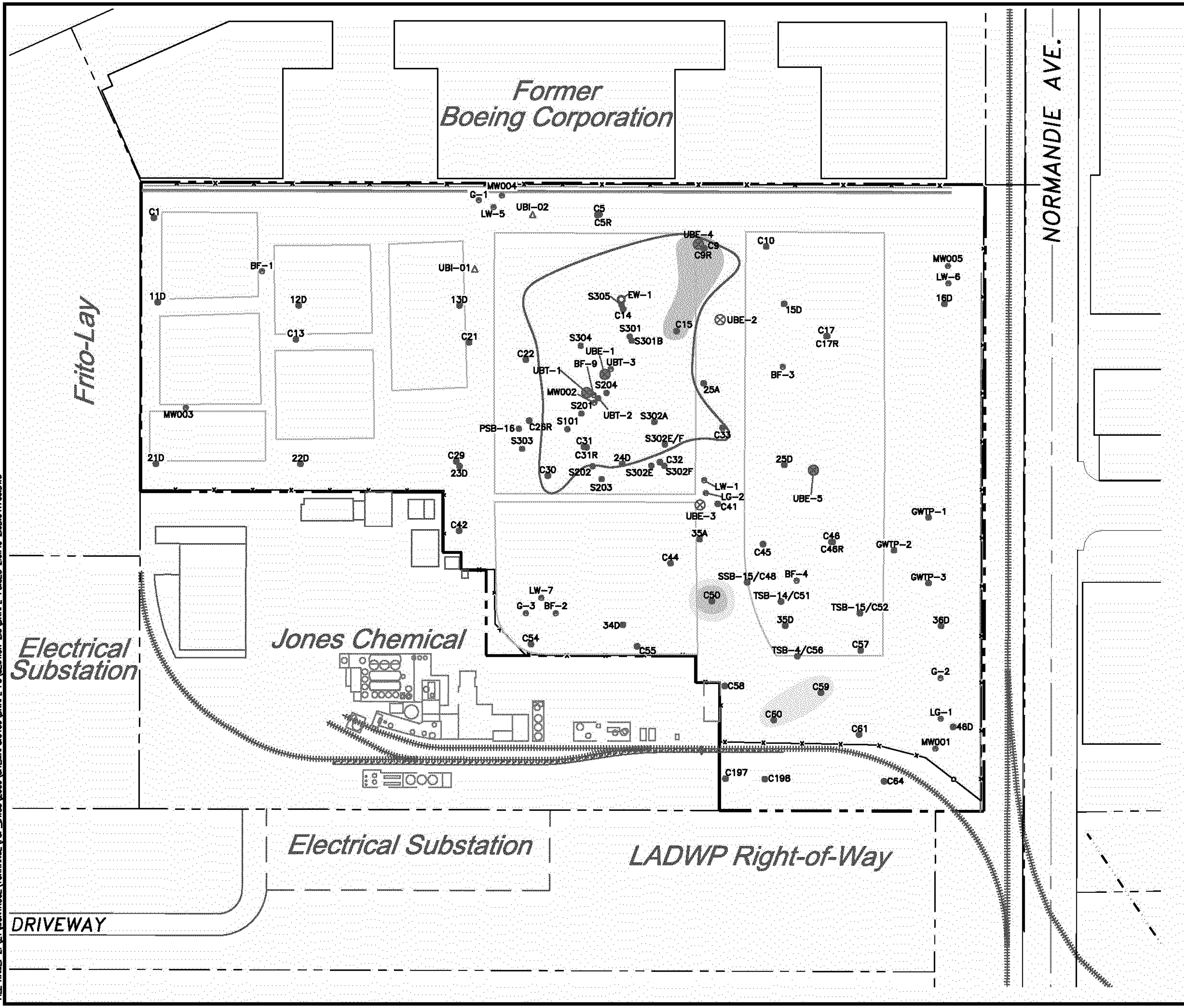
1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc., Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

Montrose Chemical Corporation

Maximum Chloroform Concentration in the Unsaturated Zone (0-25 Feet bgs)

Date: 02-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.6a

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2008\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.6A.041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Maximum Chloroform Isoconcentration in Soil Contour Interval 1–10 mg/kg
- Average Maximum Chloroform Isoconcentration in Soil Contour Interval 10–100 mg/kg

2008 EPA Industrial PRG = 1.5 mg/kg

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

NORTH

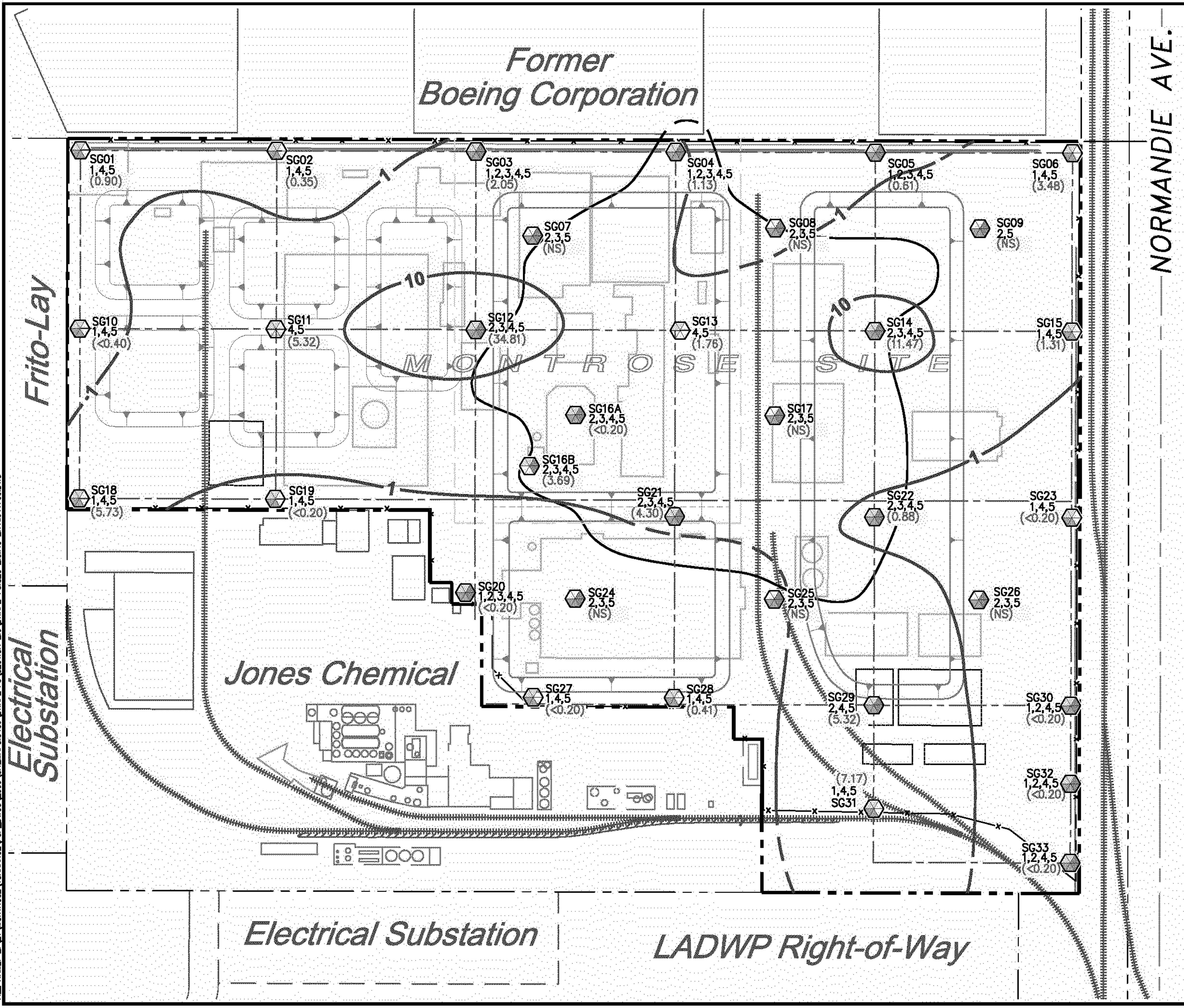
0 60 120 FEET

SCALE: 1" = 120'

Montrose Chemical Corporation

Maximum Chloroform Concentration in the Unsaturated Zone (25-60 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.8b



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — Chloroform Concentrations Reported in ppmv at 5-Feet Below Grade Surface (BGS)
- 10 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

References:

1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

Montrose Chemical Corporation

Chloroform in Soil Gas
(5 Feet bgs)

Date: 04-09

Montrose Superfund Site

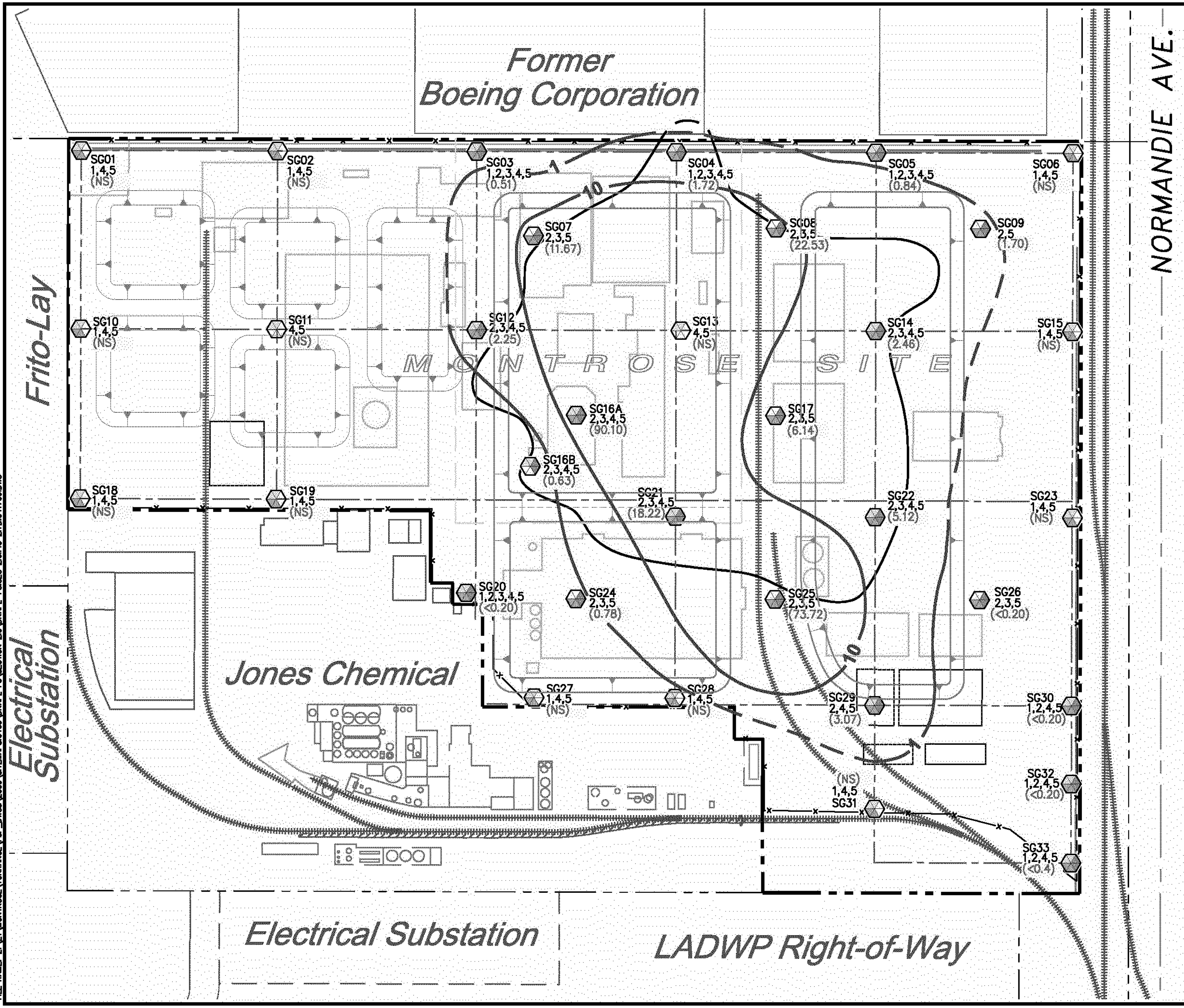
Project No. 103649

EARTH TECH | AECOM

Figure 2.7a

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL_FS\SECTION_2.0\DNAPL-FS.SEC_2.0.FIG_2.7A.041709.DWG

BOE-C6-0059683



FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.7B.041709.DWG

Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — Chloroform Concentrations Reported in ppmv at 15-Feet Below Grade Surface (BGS)
- 10 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

References:

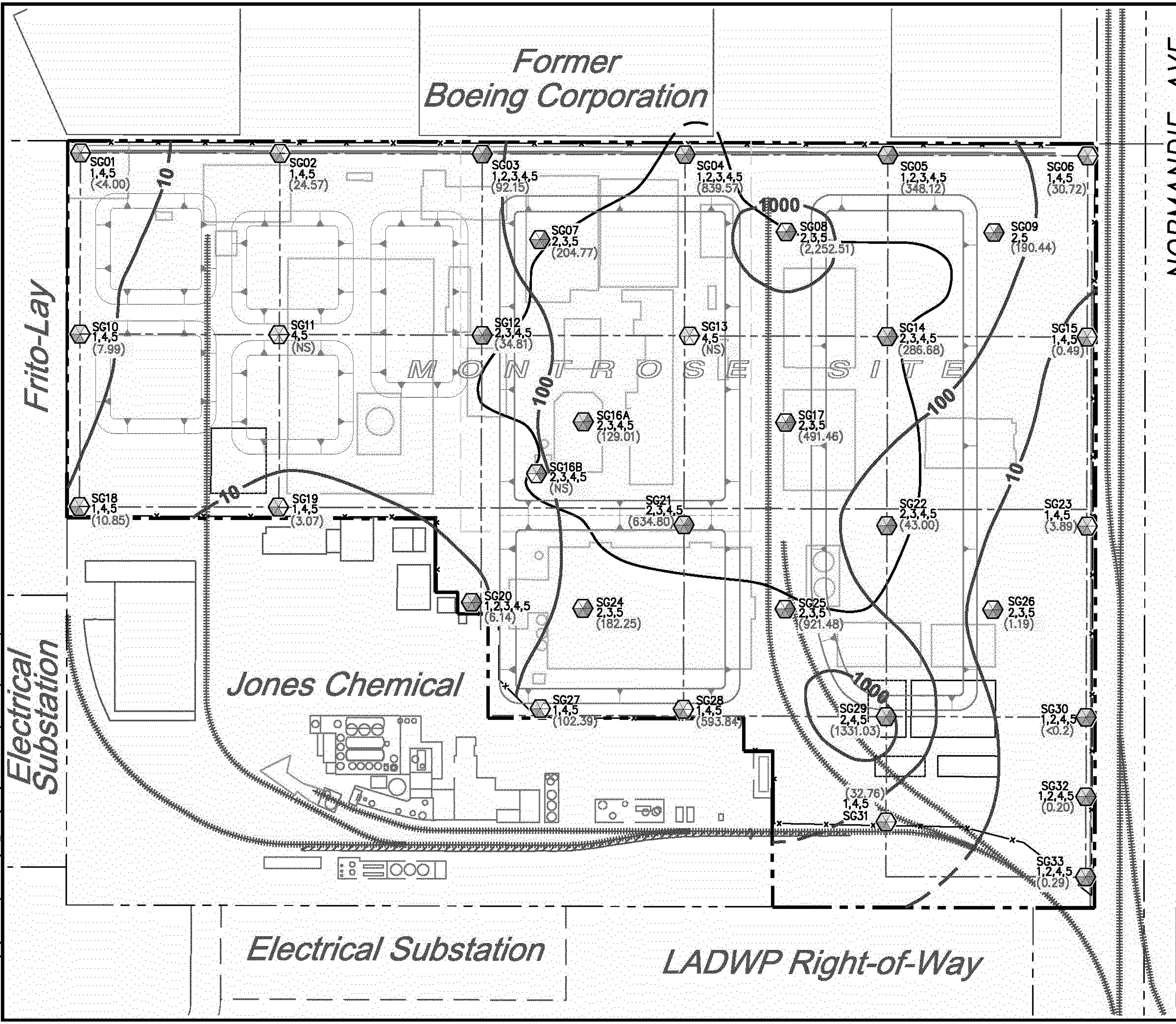
1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

Montrose Chemical Corporation

Chloroform in Soil Gas
(15 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	2.7b

BOE-C6-0059684



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — Chloroform Concentrations Reported in ppmv at 35-Feet Below Grade Surface (BGS)
- 10 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

References:

1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

NORTH
0 50 100 FEET
SCALE: 1"= 100'

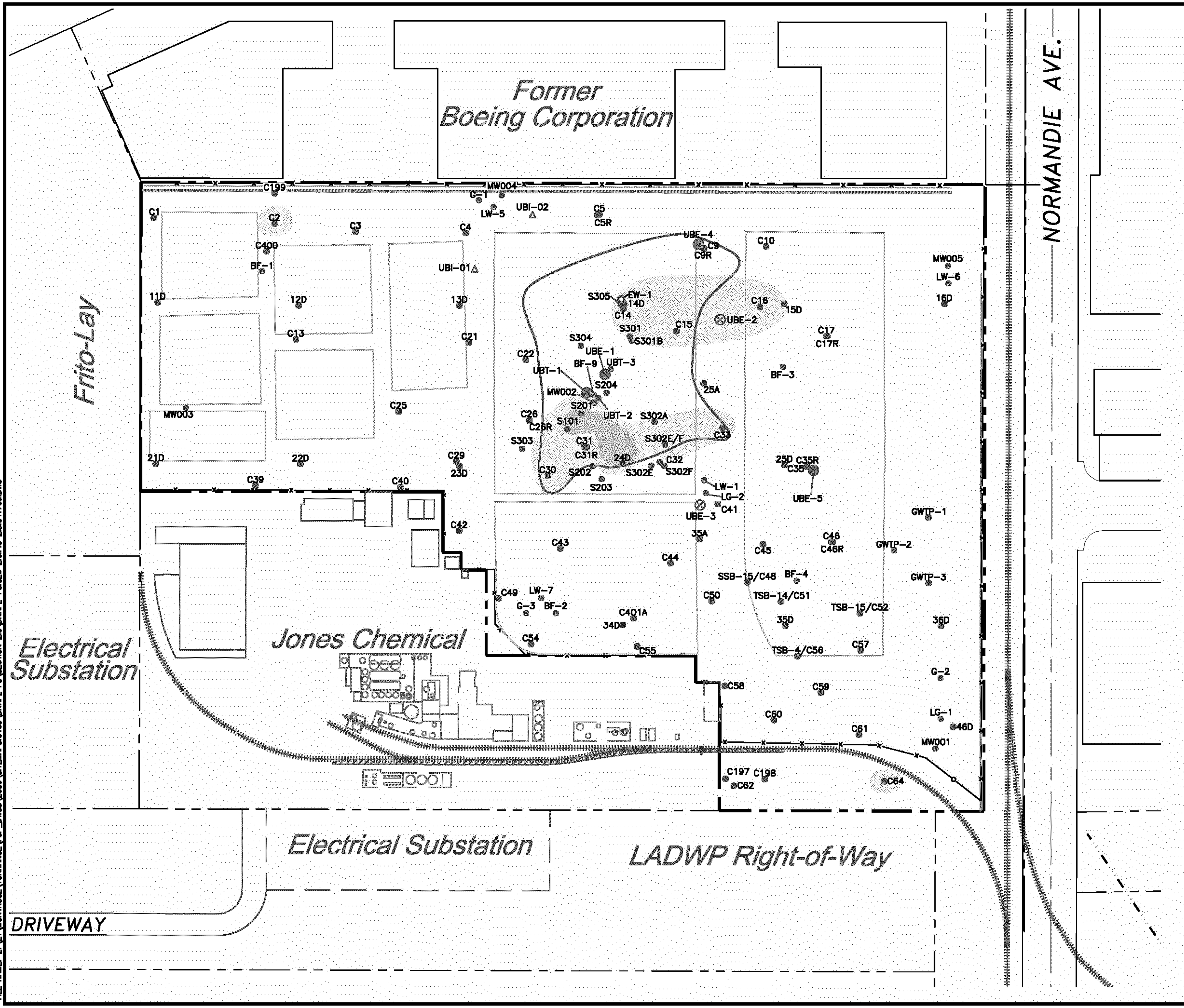
Montrose Chemical Corporation

Chloroform in Soil Gas
(35 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.7c

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.7C.041709.DWG

BOE-C6-0059685



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Maximum 1,4-DCB Isoconcentration in Soil Contour Interval 10–100 mg/kg
- Average Maximum 1,4-DCB Isoconcentration in Soil Contour Interval 100–1,000 mg/kg

2008 EPA Industrial PRG = 13 mg/kg

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

NORTH

0 60 120 FEET

SCALE: 1"= 120'

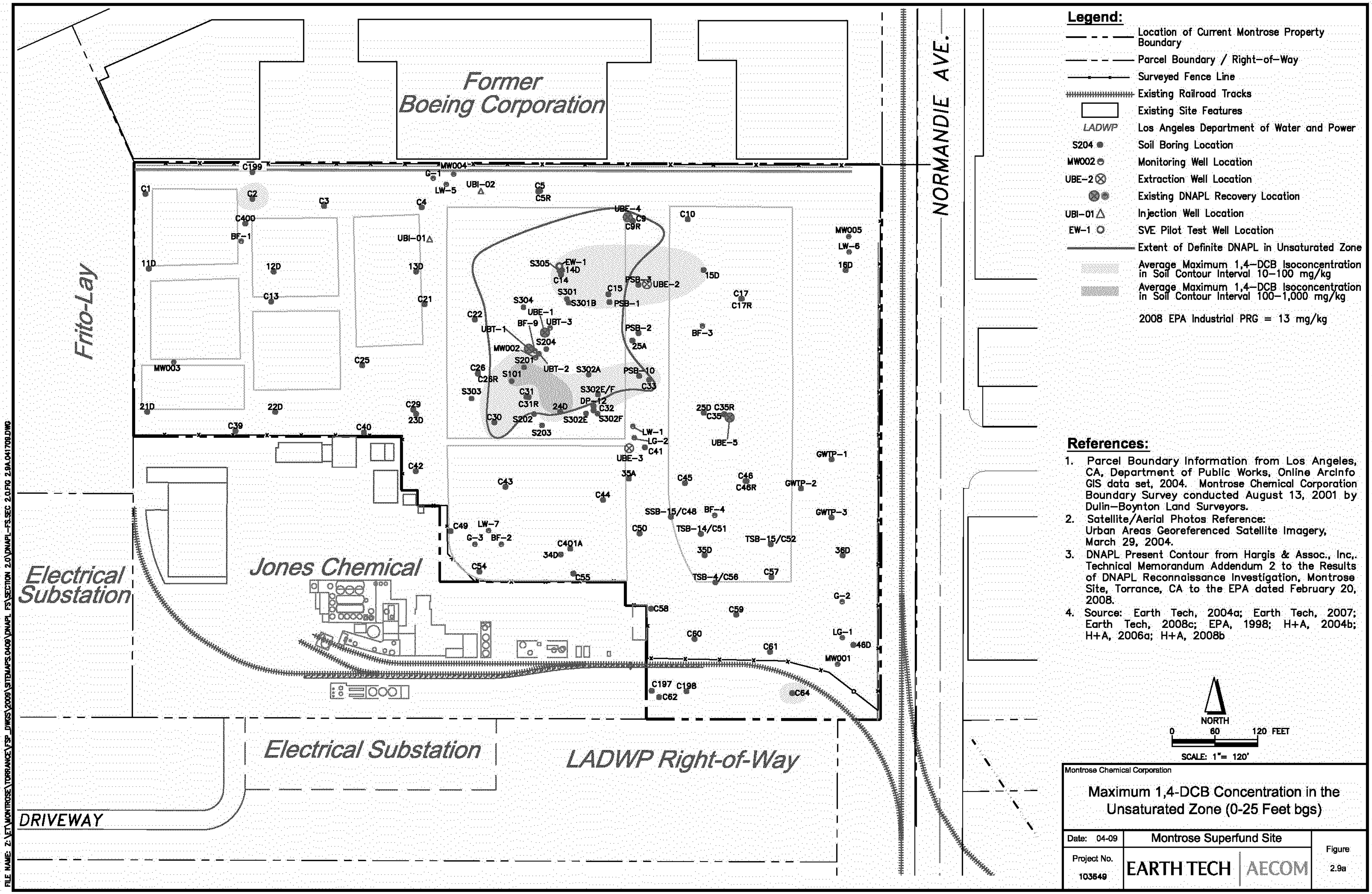
Montrose Chemical Corporation

Maximum 1,4-DCB Concentration in the Unsaturated Zone (0-60 Feet bgs)

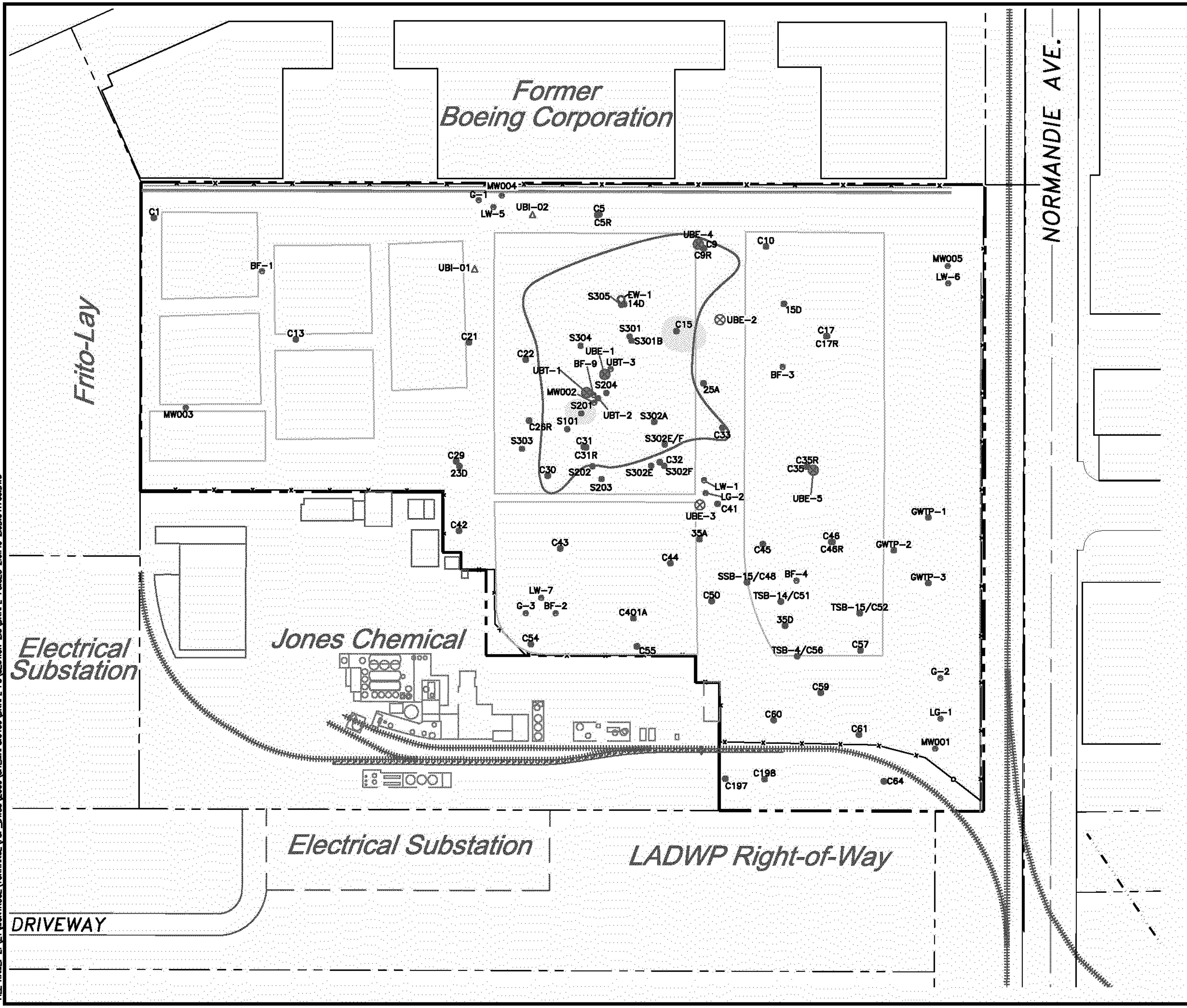
Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	2.8

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL_FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.8.041709.DWG

BOE-C6-0059686



BOE-C6-0059687



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Maximum 1,4-DCB Isoconcentration in Soil Contour Interval 10–100 mg/kg

2008 EPA Industrial PRG = 13 mg/kg

References:

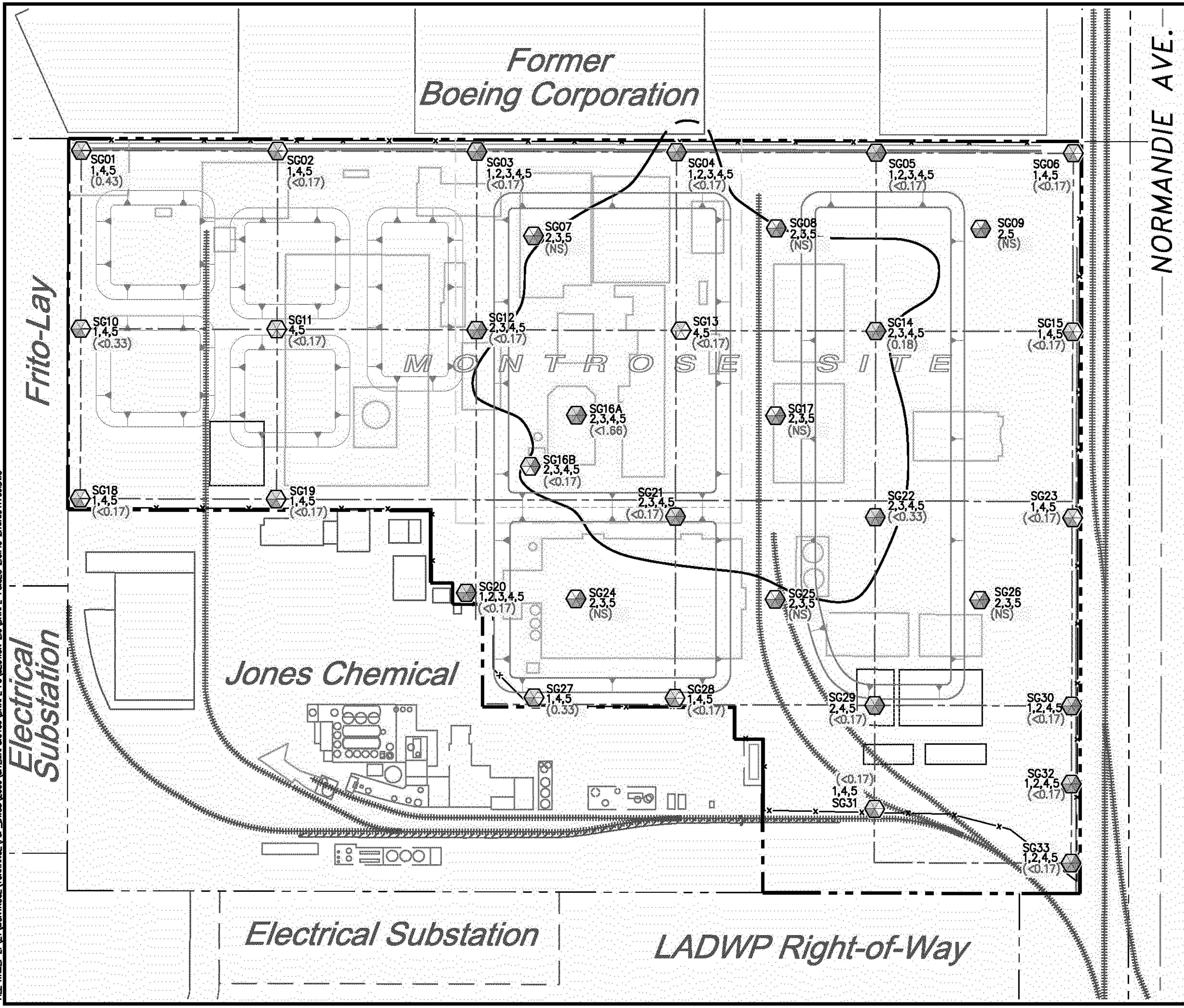
1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

Montrose Chemical Corporation

Maximum 1,4-DCB Concentration in the Unsaturated Zone (25-60 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.9b

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS-SEC 2.0.FIG 2.9B.041709.DWG



FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS 0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.10A.041709.DWG

Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — 1,4-Dichlorobenzene Concentrations Reported in ppmv at 5-Feet Below Grade Surface (BGS)
- 10 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

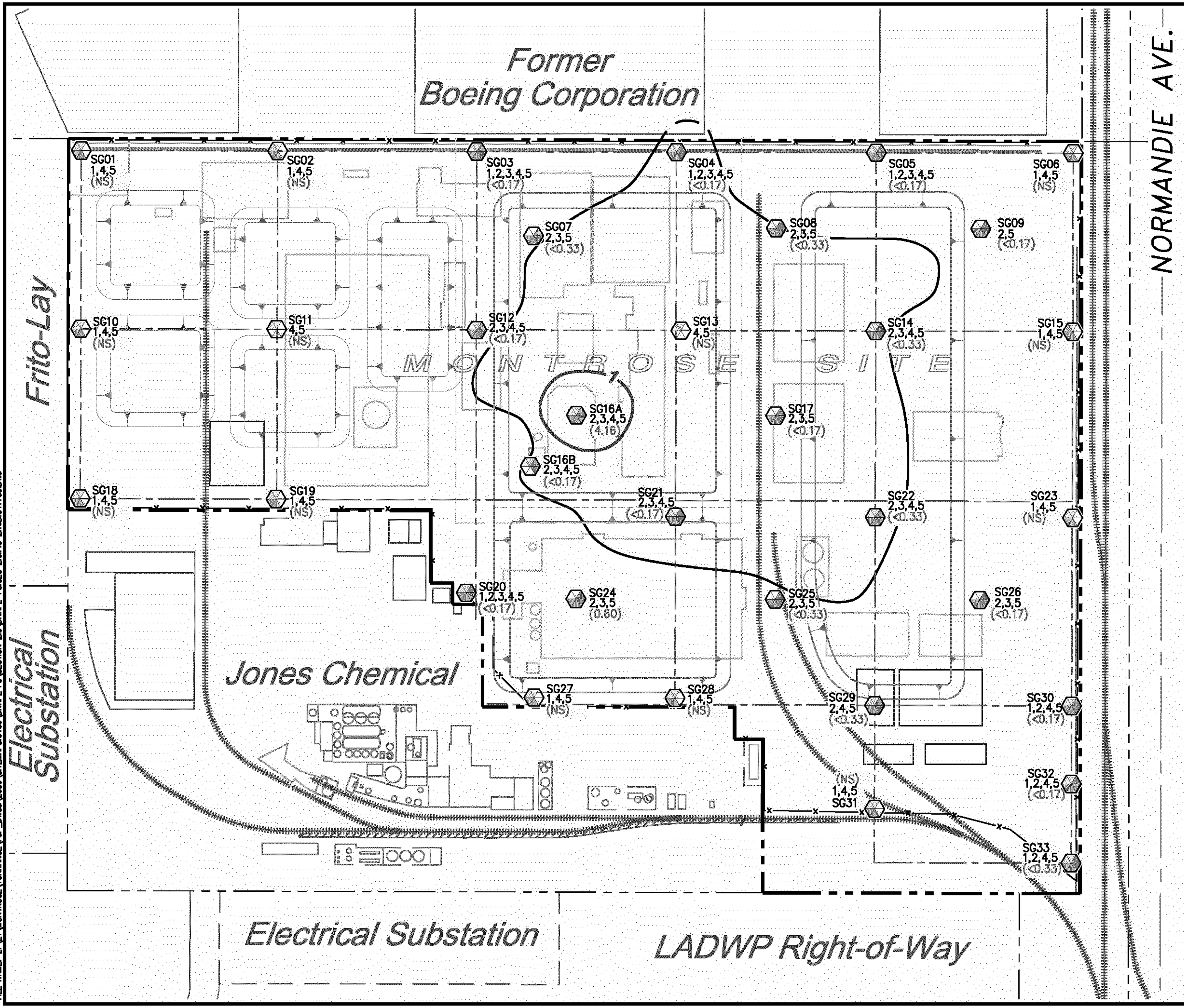
References:

1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

Montrose Chemical Corporation

1,4-DCB in Soil Gas
(5 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.10a



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — 1,4-Dichlorobenzene Concentrations Reported in ppmv at 15-Feet Below Grade Surface (BGS)
- 1 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

References:

1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004. Continental Aerial, circa 1962. Continental Aerial, circa 1981. TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

NORTH
0 50 100 FEET
SCALE: 1"= 100'

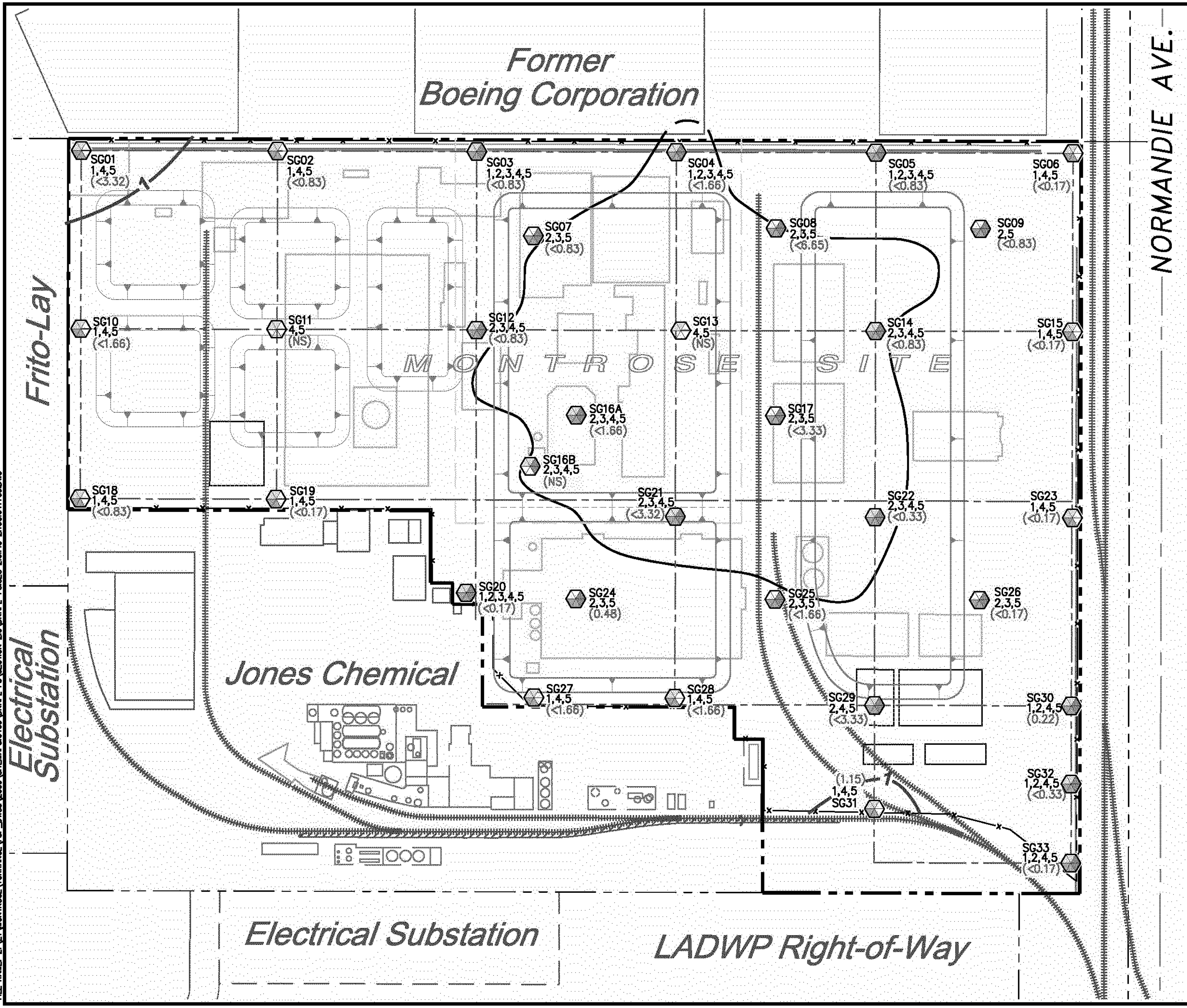
Montrose Chemical Corporation

1,4-DCB in Soil Gas
(15 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	2.10b

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS\0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.10B.041709.DWG

BOE-C6-0059690



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — 1,4-Dichlorobenzene Concentrations Reported in ppmv at 35-Feet Below Grade Surface (BGS)
- 1 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

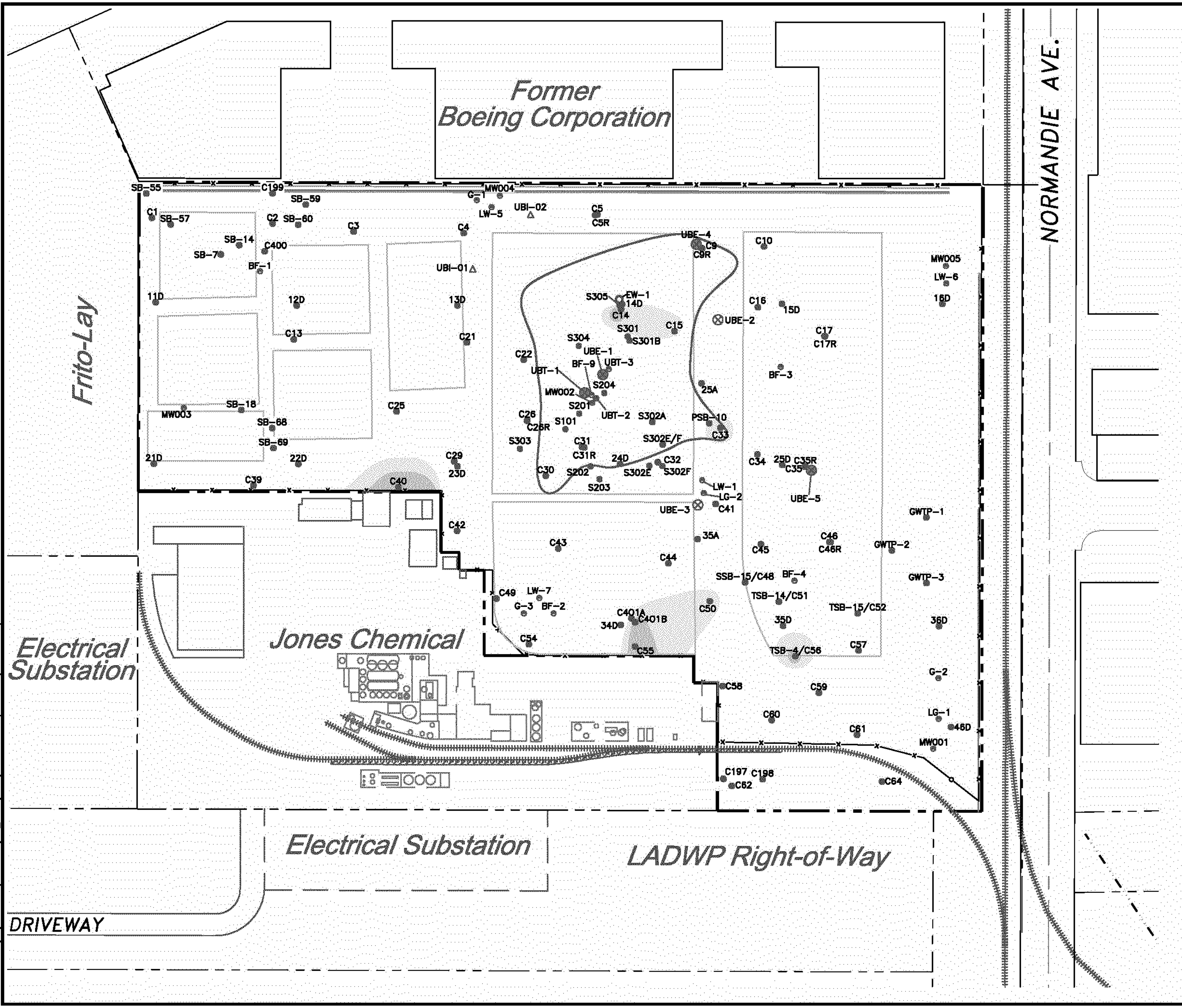
References:

1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

Montrose Chemical Corporation		
1,4-DCB in Soil Gas (35 Feet bgs)		
Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.10c

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.10C.041709.DWG

BOE-C6-0059691



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Maximum PCE Isoconcentration in Soil Contour Interval 1-10 mg/kg
- Average Maximum PCE Isoconcentration in Soil Contour Interval 10-100 mg/kg

2008 EPA Industrial PRG = 2.7 mg/kg

References:

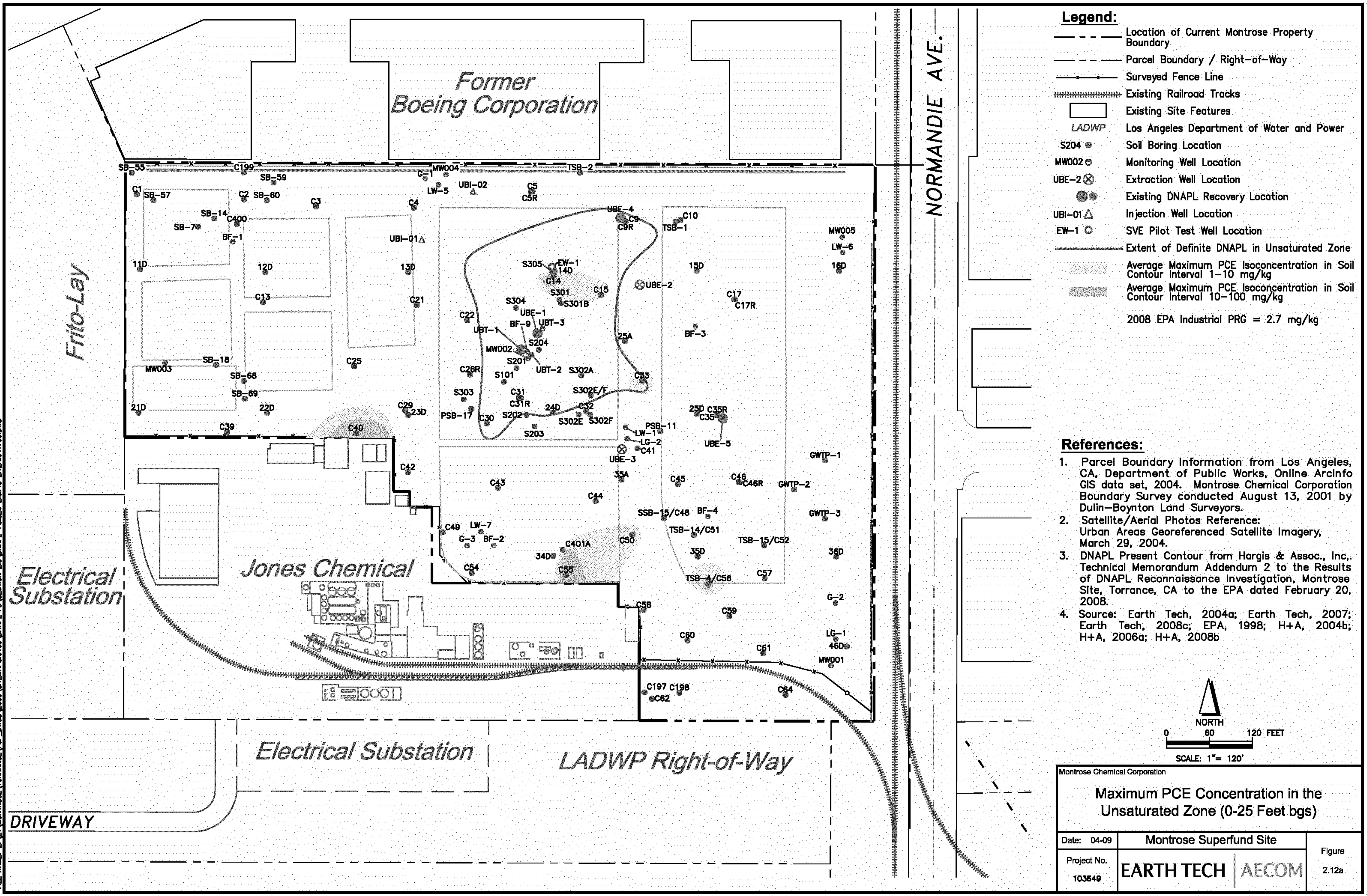
1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

Montrose Chemical Corporation

Maximum PCE Concentration in the Unsaturated Zone (0-60 Feet bgs)

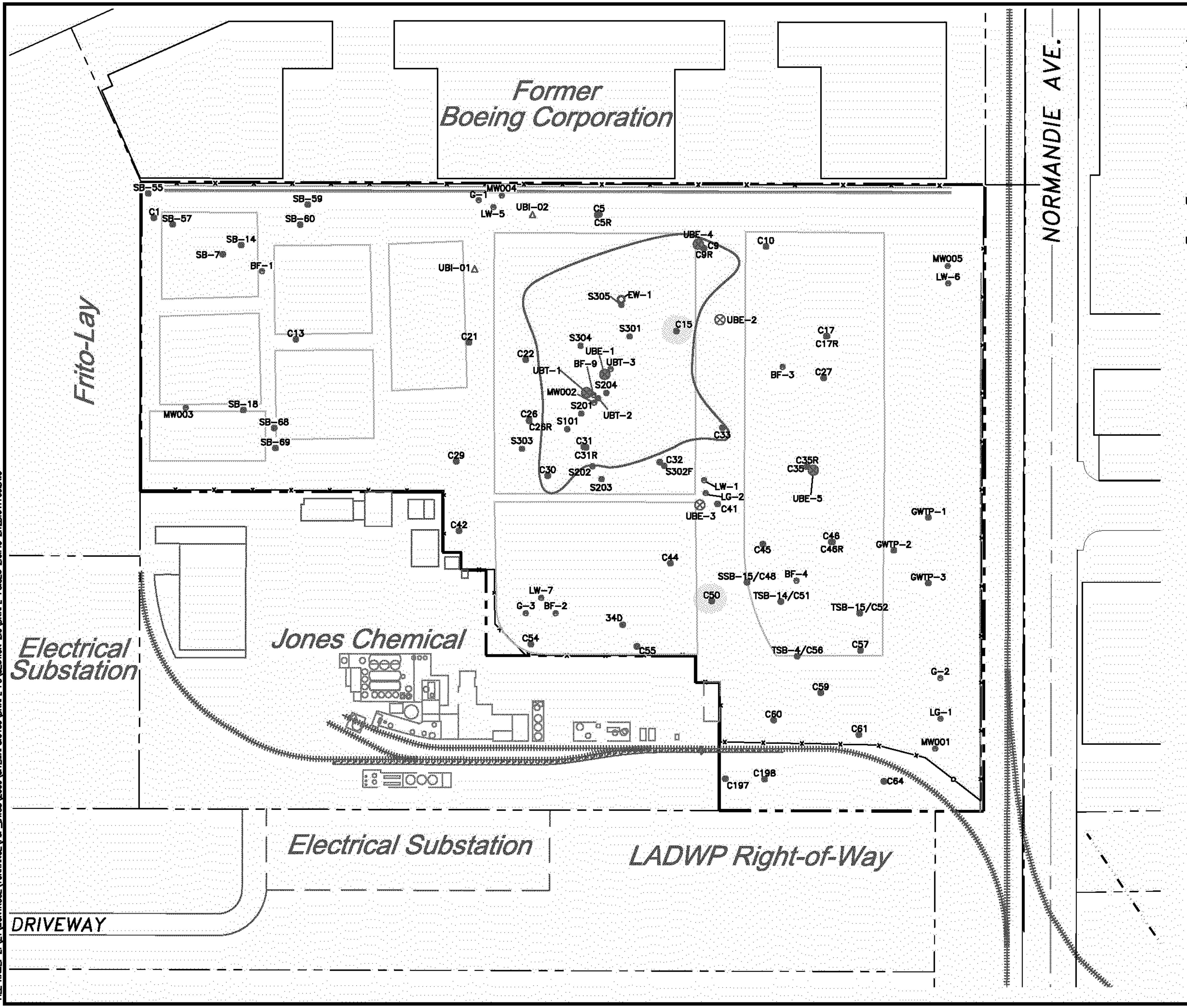
Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	2.11

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.11.041709.DWG



FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.12A.041709.DWG

BOE-C6-0059693



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Maximum PCE Isoconcentration in Soil Contour Interval 1–10 mg/kg

2008 EPA Industrial PRG = 2.7 mg/kg

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

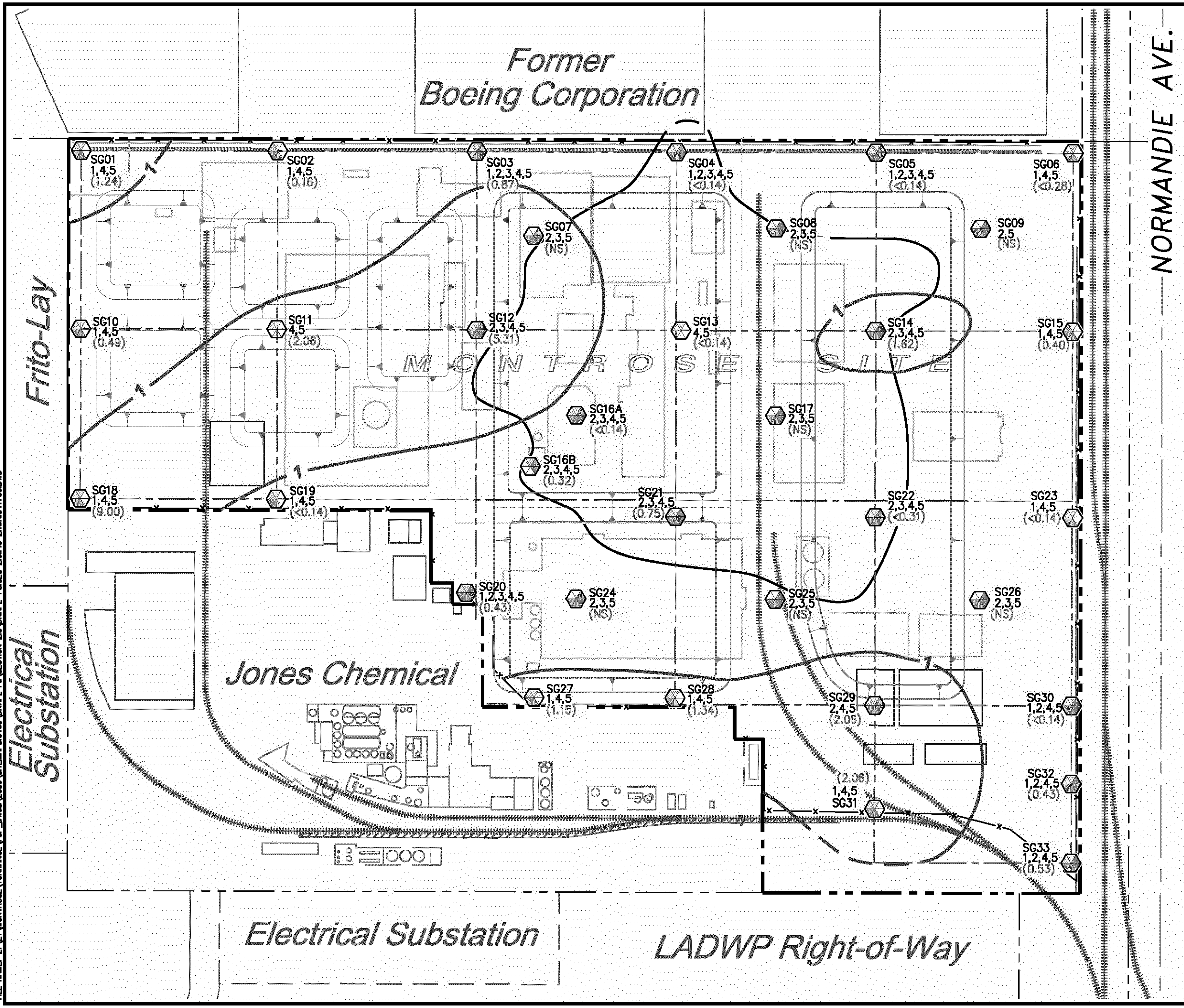
Montrose Chemical Corporation

Maximum PCE Concentration in the Unsaturated Zone (25-60 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	2.12b

FILE NAME: Z:\ET_MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS 0409\DNAPL FS\SECTION 2.0\DNAPL-FS SEC 2.0 FIG 2.12B 041709.DWG

BOE-C6-0059694



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — PCE Concentrations Reported in ppmv at 5-Feet Below Grade Surface (BGS)
- 1 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

References:

1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

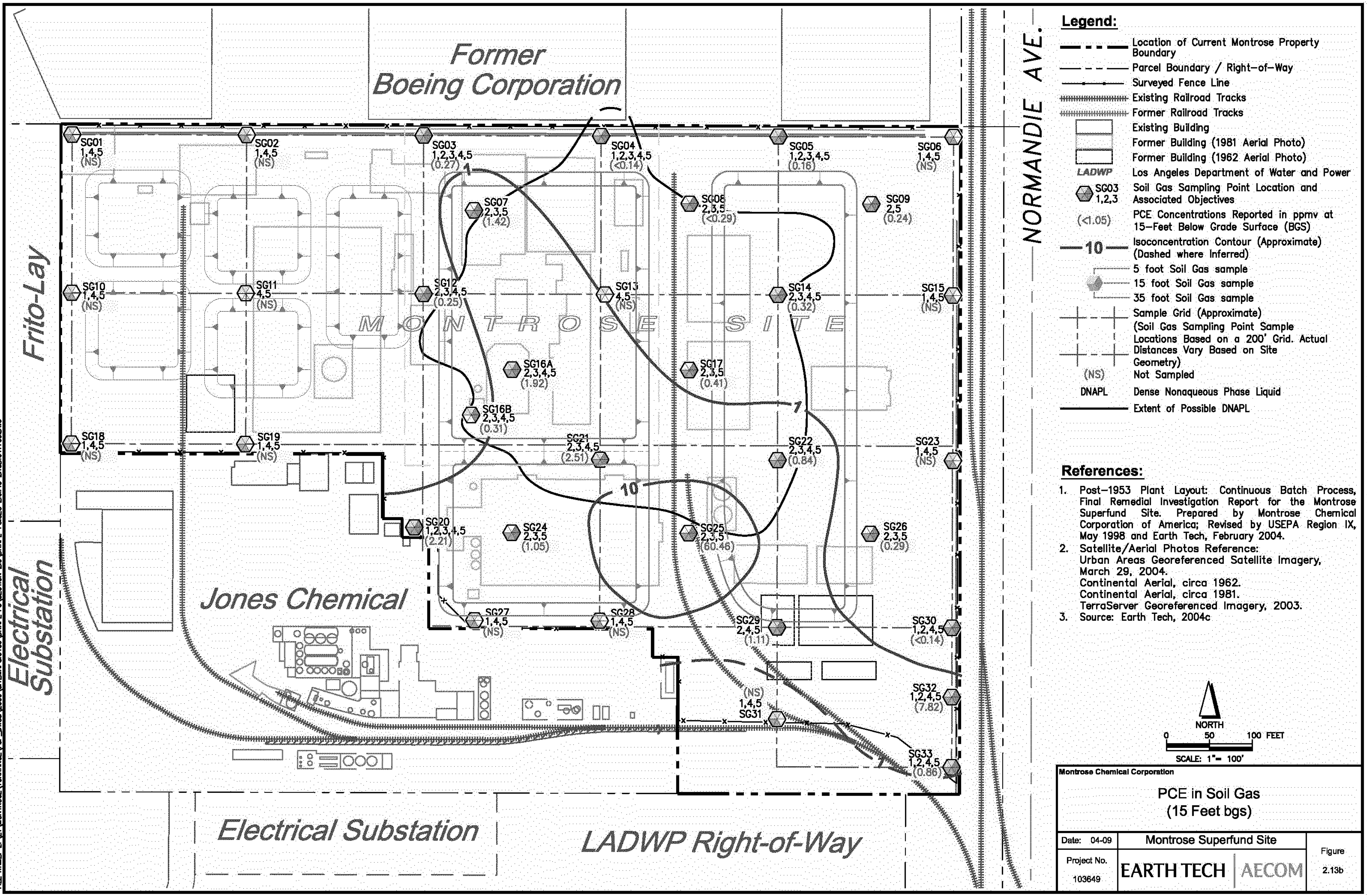
Montrose Chemical Corporation

PCE in Soil Gas
(5 Feet bgs)

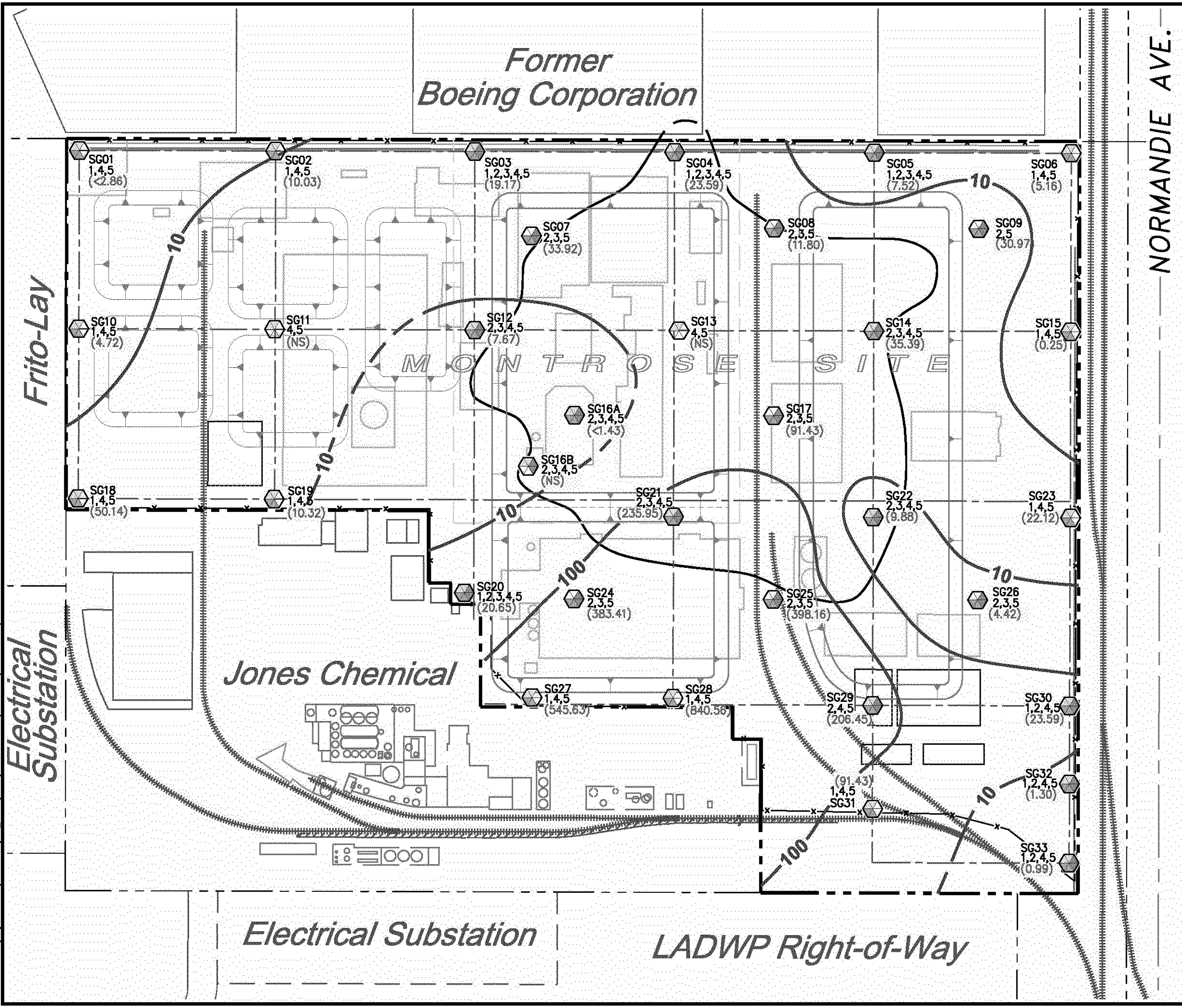
Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.13a

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\SITEMAPS\0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.13A.041709.DWG

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2008\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.13B.041709.DWG



BOE-C6-0059696



Legend:

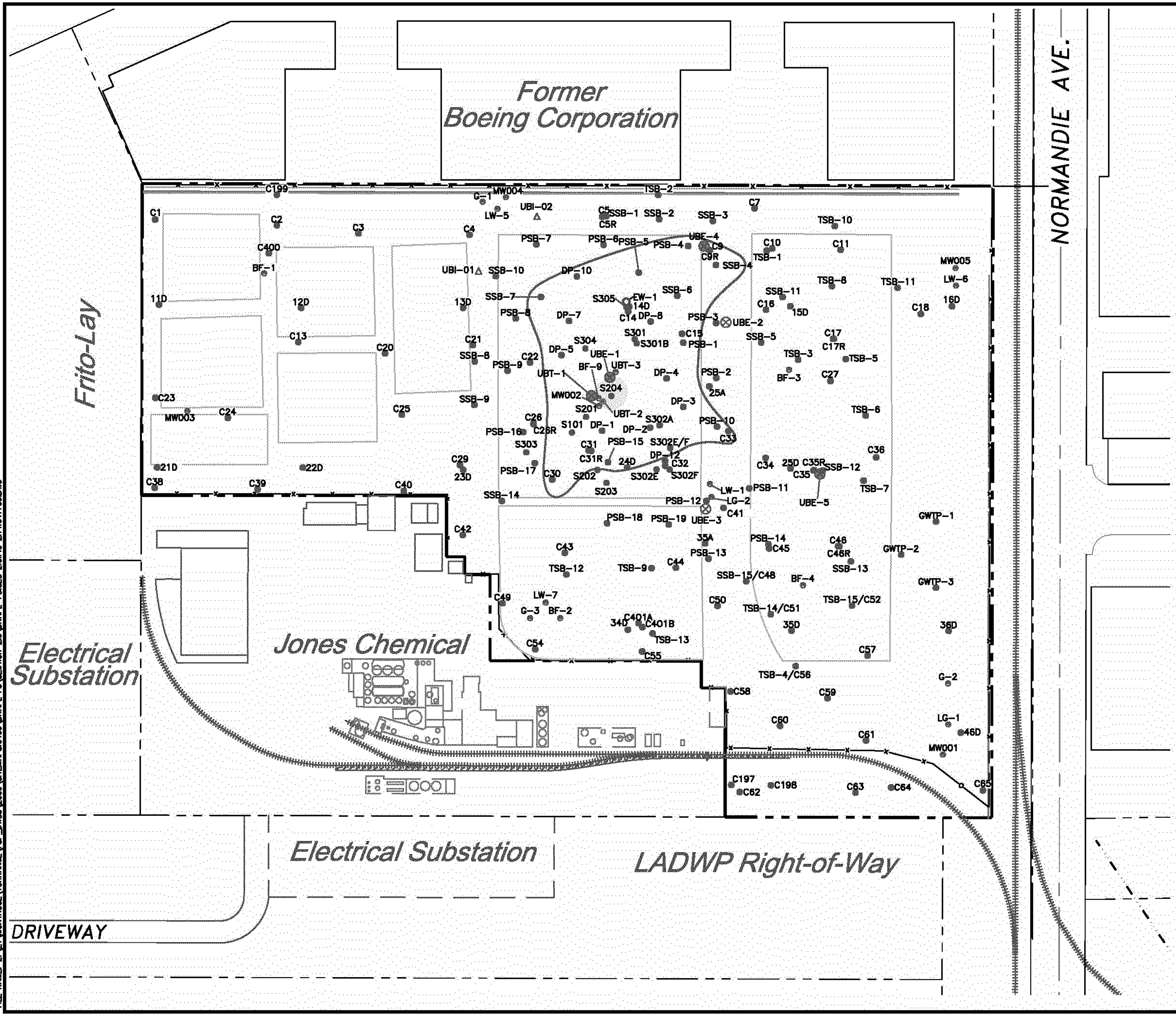
- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — PCE Concentrations Reported in ppmv at 35-Feet Below Grade Surface (BGS)
- 10 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

References:

1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004. Continental Aerial, circa 1962. Continental Aerial, circa 1981. TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

Montrose Chemical Corporation		
PCE in Soil Gas (35 Feet bgs)		
Date: 04-09	Montrose Superfund Site	Figure 2.13c
Project No. 103649	EARTH TECH AECOM	

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.13C.041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Maximum Benzene Isoconcentration in Soil Contour Interval 10–100 mg/kg

2008 EPA Industrial PRG = 5.6 mg/kg

References:

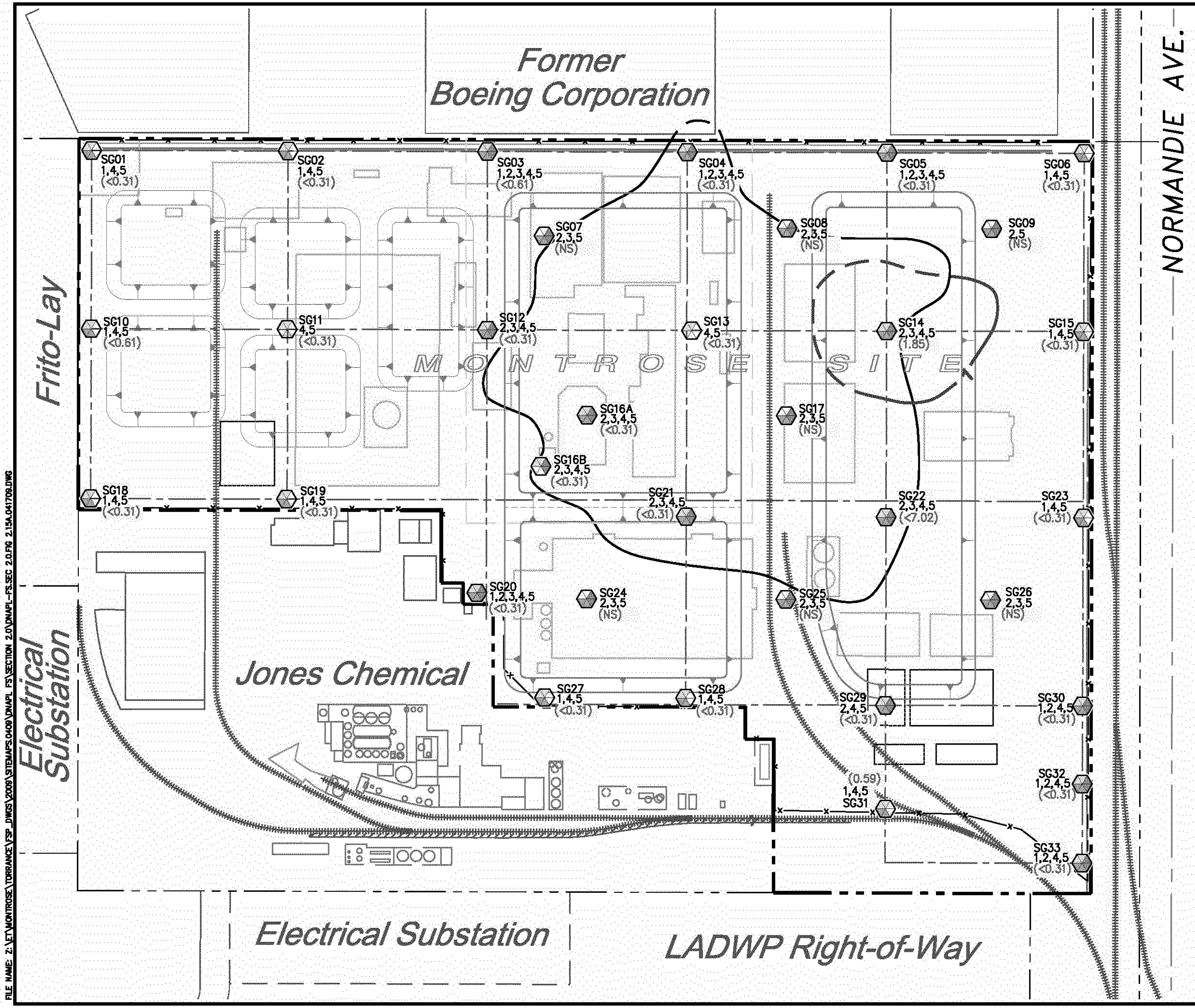
1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

Montrose Chemical Corporation

Maximum Benzene Concentration in the Unsaturated Zone (0-60 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.14

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.14.041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — Benzene Concentrations Reported in ppmv at 5-Feet Below Grade Surface (BGS)
- 1 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

References:

1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

NORTH

0 50 100 FEET

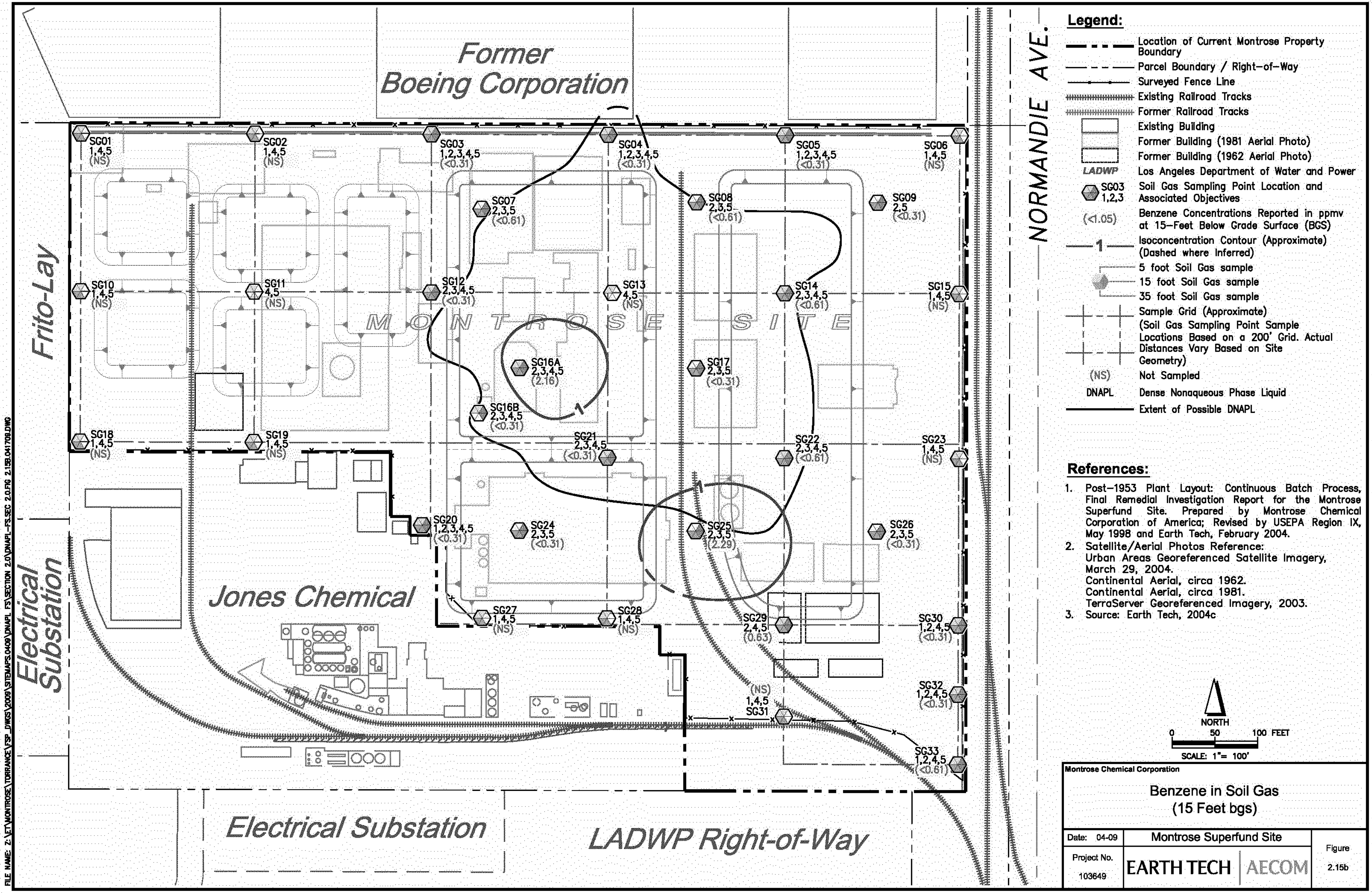
SCALE: 1"= 100'

Montrose Chemical Corporation

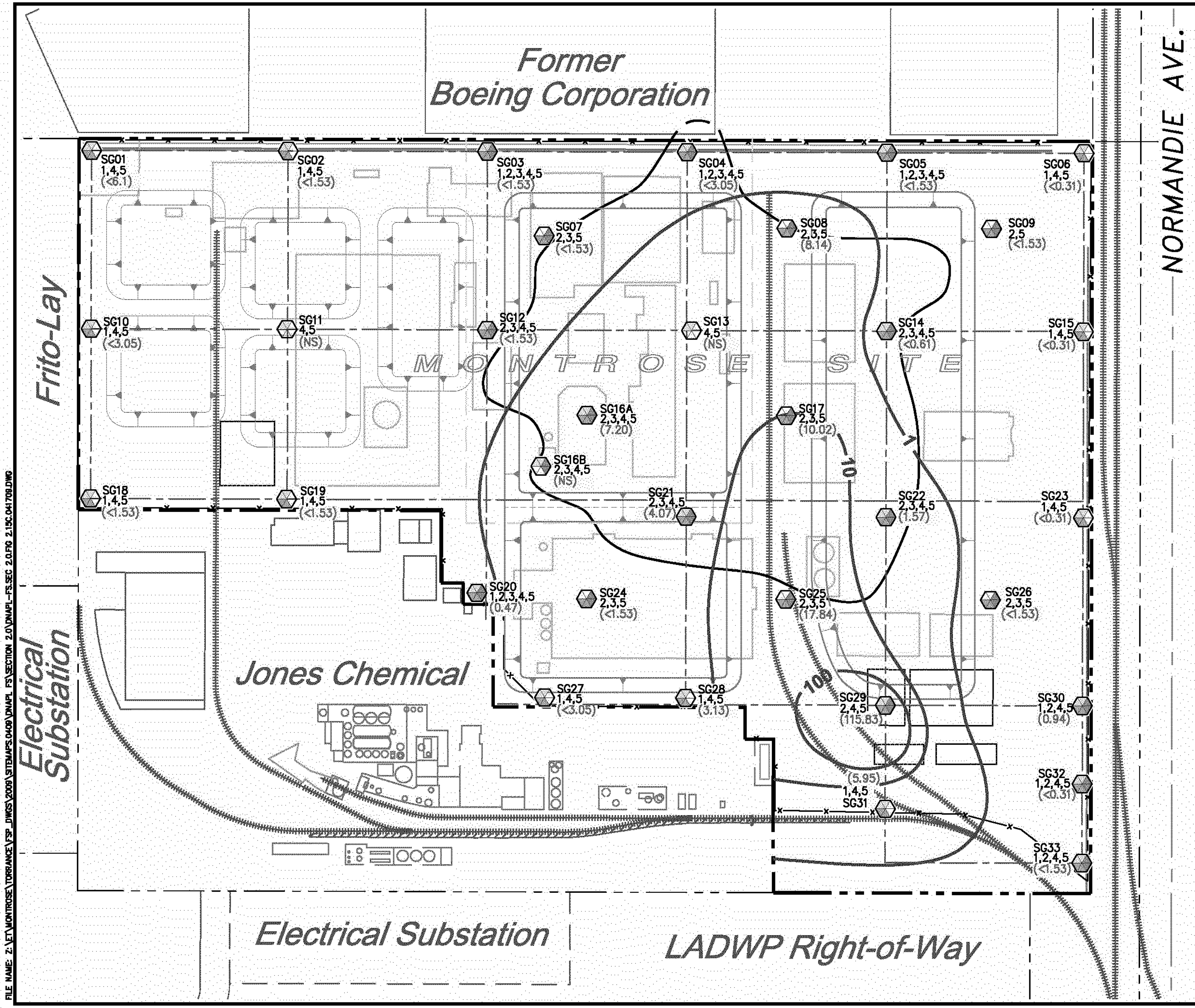
Benzene in Soil Gas
(5 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.15a

BOE-C6-0059699



BOE-C6-0059700



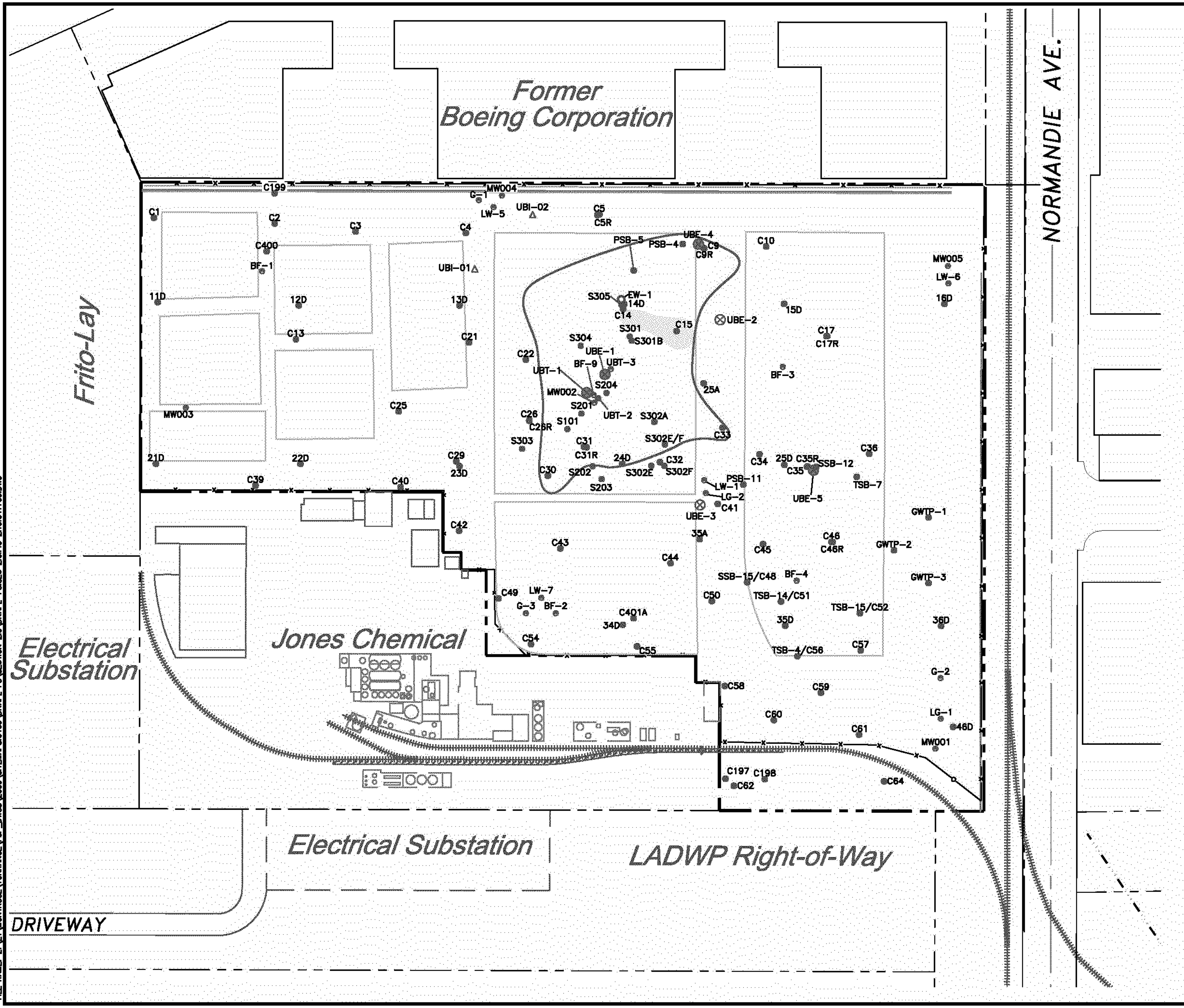
Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — Benzene Concentrations Reported in ppmv at 35-Feet Below Grade Surface (BGS)
- 10 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

References:

1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

Montrose Chemical Corporation		
Benzene in Soil Gas (35 Feet bgs)		
Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	2.15c



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Maximum Carbon Tetrachloride Isoconcentration in Soil Contour Interval 1–10 mg/kg

2008 EPA Industrial PRG = 1.3 mg/kg

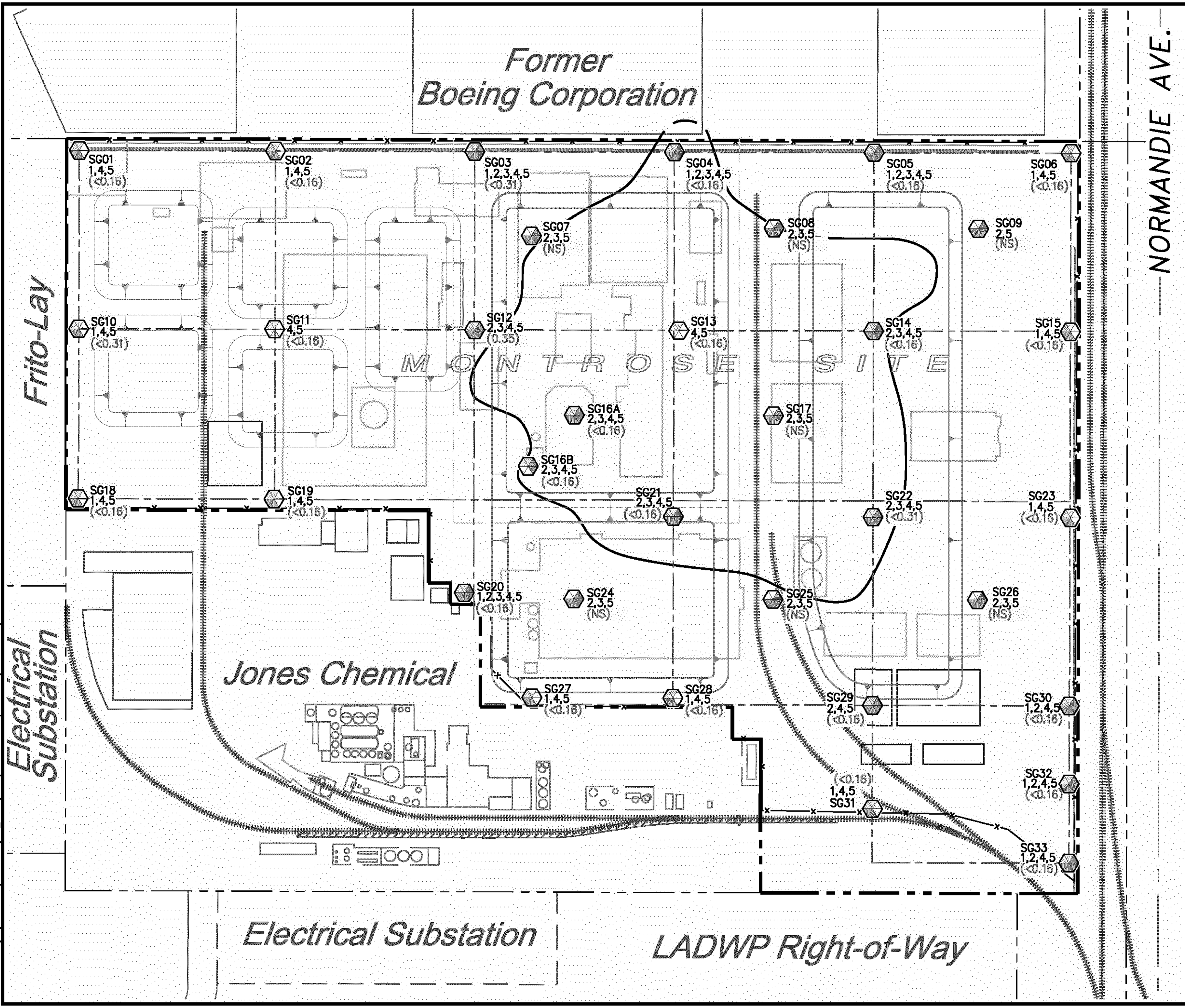
References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

Montrose Chemical Corporation

Maximum Carbon Tetrachloride Concentration in the Unsaturated Zone (0-60 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	2.16



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — Carbon Tetrachloride Concentrations Reported in ppmv at 5-Feet Below Grade Surface (BGS)
- 10 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

References:

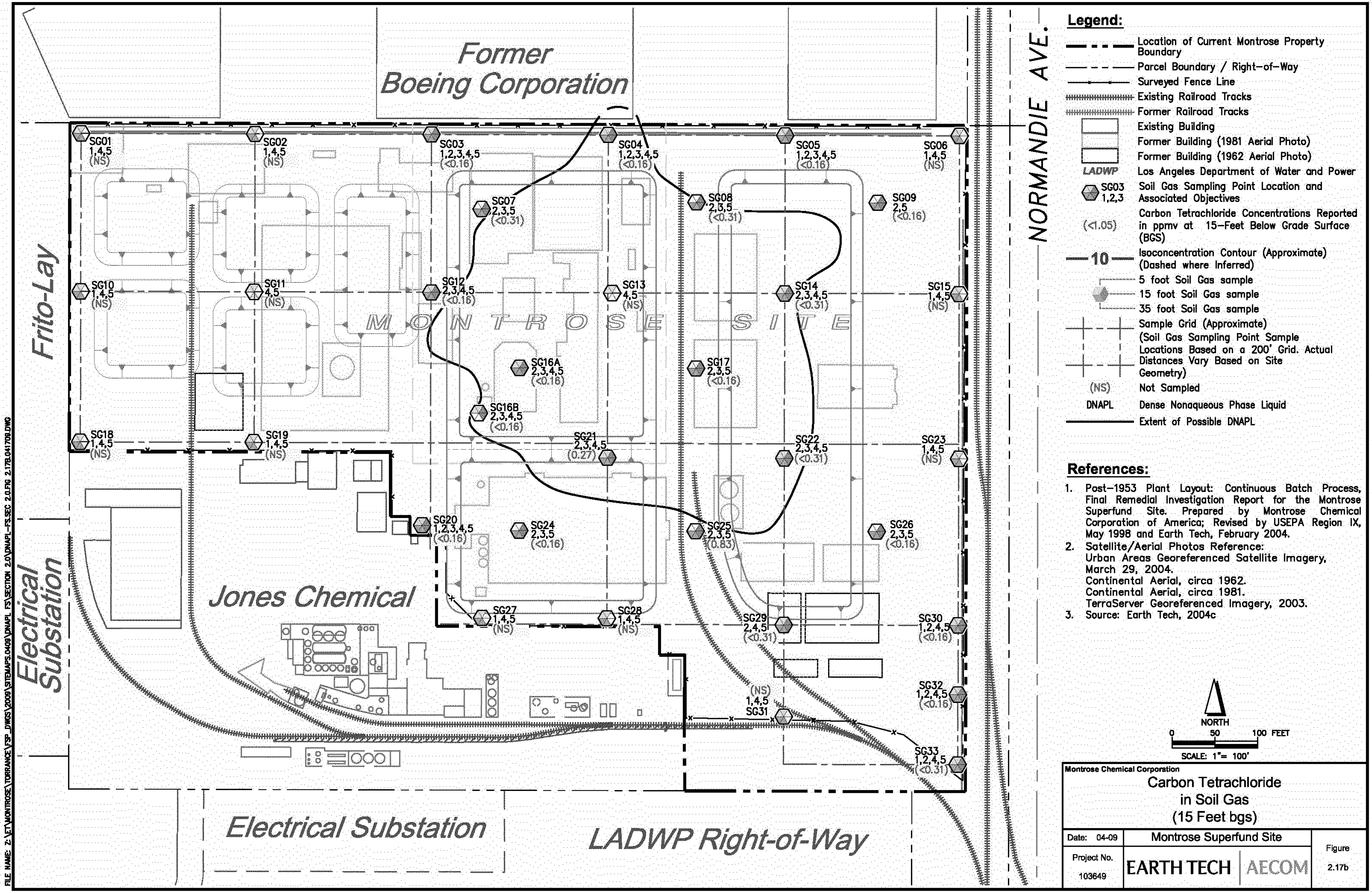
1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

Montrose Chemical Corporation

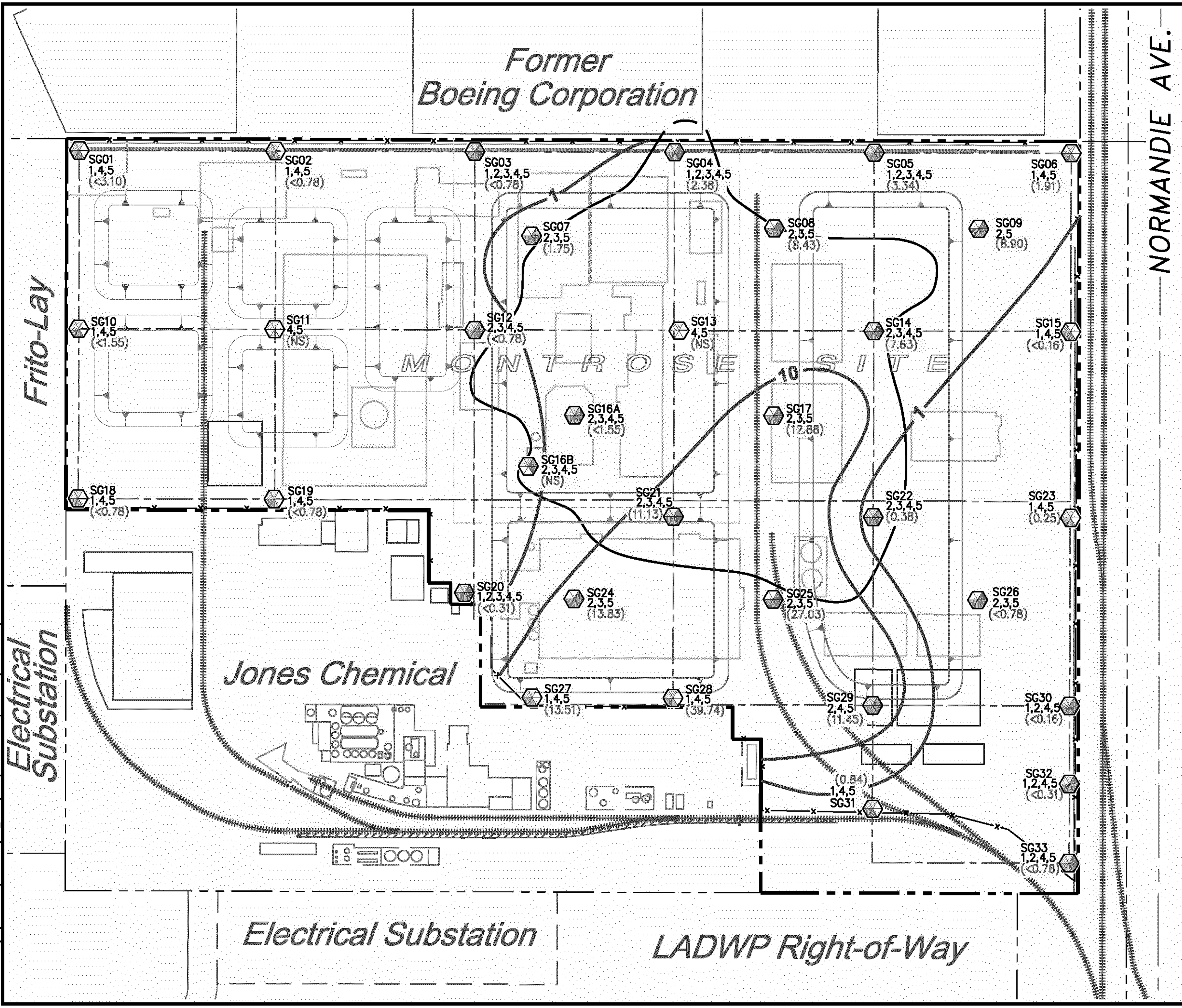
Carbon Tetrachloride
in Soil Gas
(5 Feet bgs)

Date: 04-09	Montrose Superfund Site	Figure 2.17a
Project No. 103649	EARTH TECH AECOM	

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL_FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.17A.041709.DWG



BOE-C6-0059704



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- Former Building (1981 Aerial Photo)
- Former Building (1962 Aerial Photo)
- LADWP — Los Angeles Department of Water and Power
- SG03 1,2,3 — Soil Gas Sampling Point Location and Associated Objectives
- (<1.05) — Carbon Tetrachloride Concentrations Reported in ppmv at 35-Feet Below Grade Surface (BGS)
- 10 — Isoconcentration Contour (Approximate) (Dashed where Inferred)
- 5 foot Soil Gas sample
- 15 foot Soil Gas sample
- 35 foot Soil Gas sample
- Sample Grid (Approximate) (Soil Gas Sampling Point Sample Locations Based on a 200' Grid. Actual Distances Vary Based on Site Geometry)
- (NS) — Not Sampled
- DNAPL — Dense Nonaqueous Phase Liquid
- Extent of Possible DNAPL

References:

1. Post-1953 Plant Layout: Continuous Batch Process, Final Remedial Investigation Report for the Montrose Superfund Site. Prepared by Montrose Chemical Corporation of America; Revised by USEPA Region IX, May 1998 and Earth Tech, February 2004.
2. Satellite/Aerial Photos Reference:
   Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
   Continental Aerial, circa 1962.
   Continental Aerial, circa 1981.
   TerraServer Georeferenced Imagery, 2003.
3. Source: Earth Tech, 2004c

Montrose Chemical Corporation

Carbon Tetrachloride in Soil Gas (35 Feet bgs)

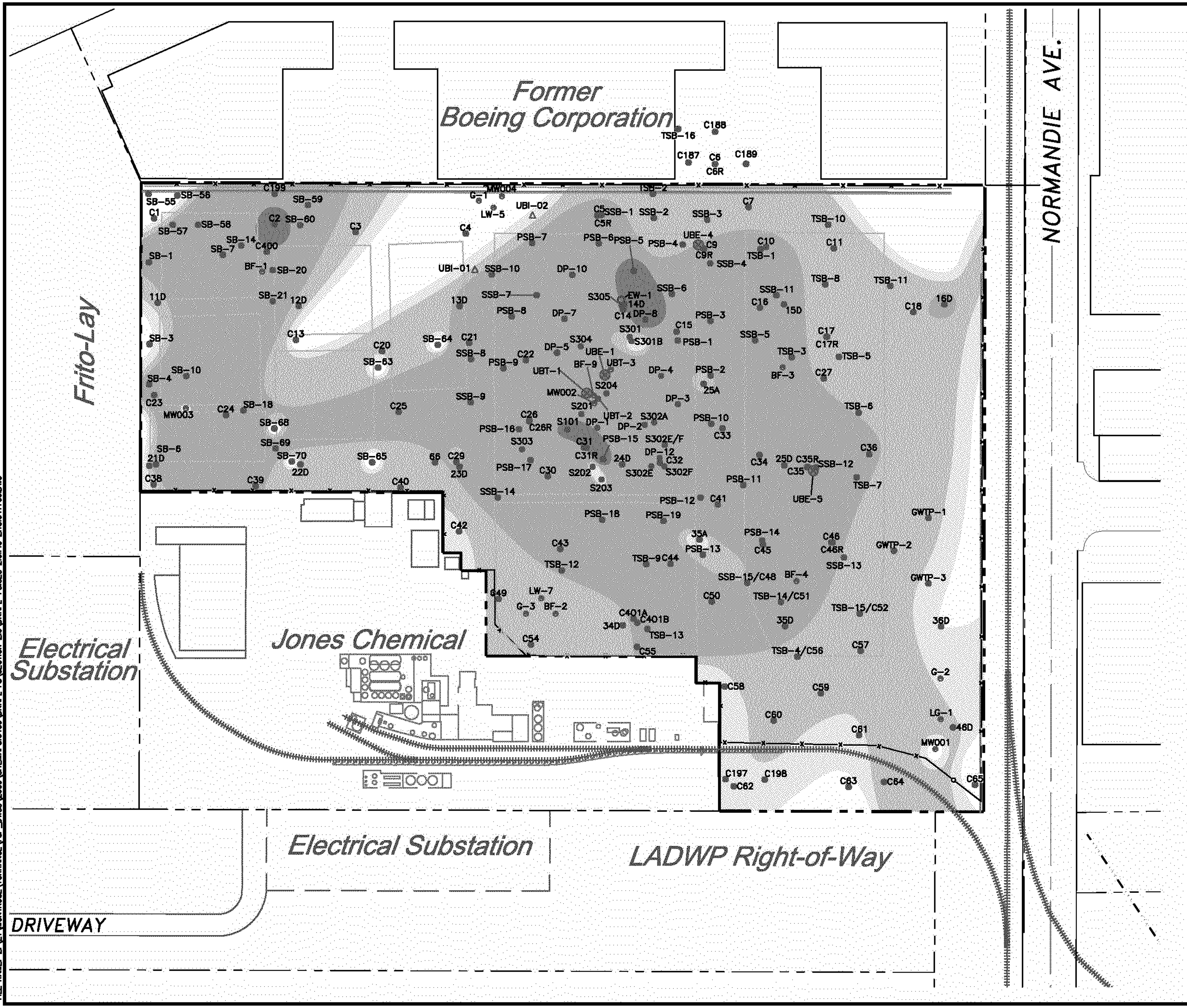
Date: 04-09

Montrose Superfund Site

Project No. 103649

EARTH TECH | AECOM

Figure 2.17c



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Site Features
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- EW-1 — SVE Pilot Test Well Location
- Average Total DDT Isoconcentration in Soil Contour Interval 10–100 mg/kg
- Average Total DDT Isoconcentration in Soil Contour Interval 100–1000 mg/kg
- Average Total DDT Isoconcentration in Soil Contour Interval 1000–10,000 mg/kg
- Average Total DDT Isoconcentration in Soil Contour Interval >10,000 mg/kg

Notes: 1. Some Isoconcentration Contours are Truncated at Montrose Property Boundary

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

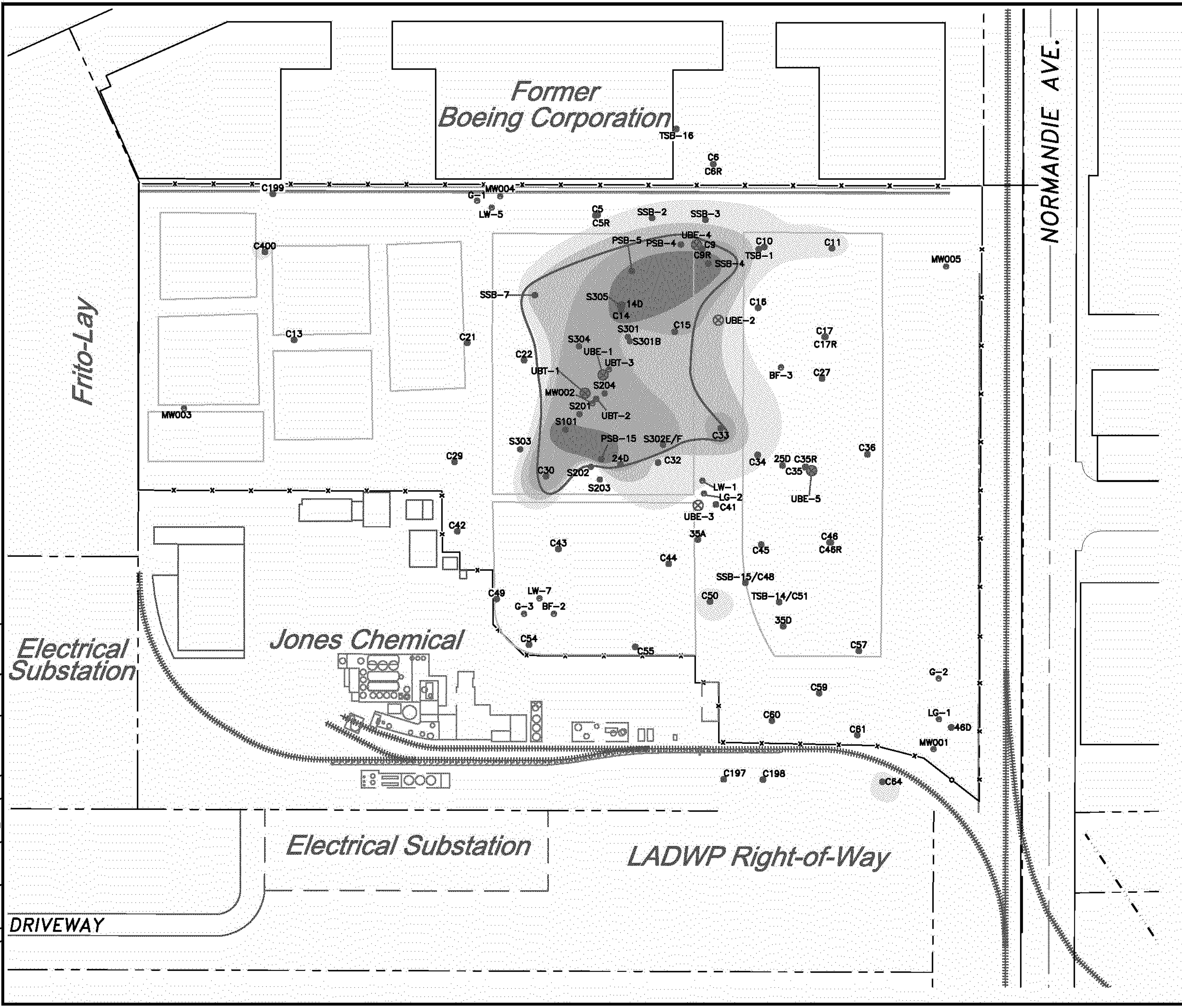
Montrose Chemical Corporation

Total DDT in the Unsaturated Zone (0 to 60 feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	2.18

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS-SEC 2.0.FIG 2.18.041709.DWG

BOE-C6-0059706



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- Extent of Definite DNAPL in Unsaturated Zone
- Average Total DDT Isoconcentration in Soil Contour Interval 10–100 mg/kg
- Average Total DDT Isoconcentration in Soil Contour Interval 100–1,000 mg/kg
- Average Total DDT Isoconcentration in Soil Contour Interval 1,000–10,000 mg/kg
- Average Total DDT Isoconcentration in Soil Contour Interval >10,000 mg/kg

Notes: 1. Some Isoconcentration Contours are Truncated at Montrose Property Boundary

References:

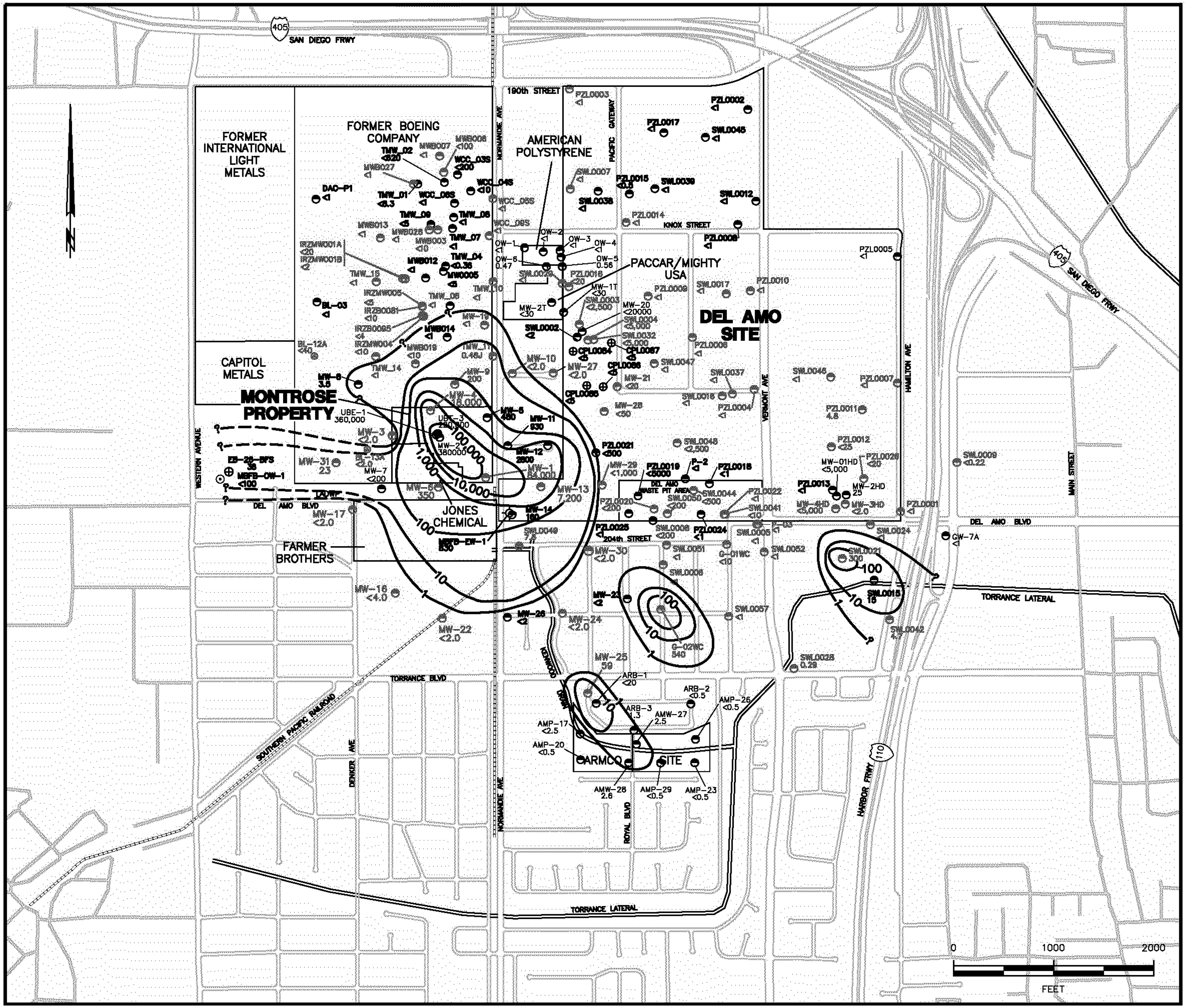
1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

Montrose Chemical Corporation

Total DDT in the Unsaturated Zone (11 to 60 feet bgs)

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.19

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.19.041709.DWG



EXPLANATION

MW-6 / 350	UPPER BELLFLOWER AQUITARD MONITOR WELL. CONCENTRATION IN MICROGRAMS PER LITER, SAMPLED SEPTEMBER – NOVEMBER 2006
MW-17 / <2	UPPER BELLFLOWER AQUITARD MONITOR WELL. CONCENTRATION IN MICROGRAMS PER LITER, COLLECTED BETWEEN 2004 AND SEPTEMBER 2006
EB-26-BFS / 38	EXPLORATORY BORING AND TEMPORARY UPPER BELLFLOWER AQUITARD MONITORING WELL
MBFB-EW-1 / 830	MIDDLE BELLFLOWER "B" EXTRACTION WELL
MBFB-OW-1 / <100	MIDDLE BELLFLOWER "B" OBSERVATION WELL
MW-2 / 380,000	UPPER BELLFLOWER AQUITARD MONITOR WELL. CONCENTRATION IN MICROGRAMS PER LITER, COLLECTED PRIOR TO 2004
CPL0084	DEL AMO TEMPORARY BELLFLOWER SAND MONITOR WELL LOCATION

?——1,000——?

CONTOUR LINE OF EQUAL CONCENTRATION OF CHLOROBENZENE IN MICROGRAMS PER LITER DASHED WHERE APPROXIMATE, QUERIED WHERE INFERRED BASED ON MOST RECENT SAMPLING RESULTS.

< = LESS THAN; NUMERICAL VALUE IS THE LIMIT OF DETECTION FOR THIS ANALYSIS.

WELL IDENTIFIER NOTES:

- MW = MONTROSE MONITOR WELLS
- G, GW, SWL, PZL, GW, P, MW-2T AND MW-3HD = DEL AMO MONITOR WELLS
- OW = AMERICAN POLYSTRENE MONITOR WELLS
- AMW, AMP, ARB = ARMCO MONITOR WELLS
- DAC, TMW, WCC, MWB = BOEING MONITOR WELLS
- BL = INDUSTRIAL LIGHT METALS MONITOR WELLS
- IRZB, IRZMW = BOEING BIOREMEDIATION WELLS

SOURCE: HARGIS + ASSOCIATES, 2007a

MONTROSE CHEMICAL CORPORATION OF CALIFORNIA
TORRANCE, CALIFORNIA

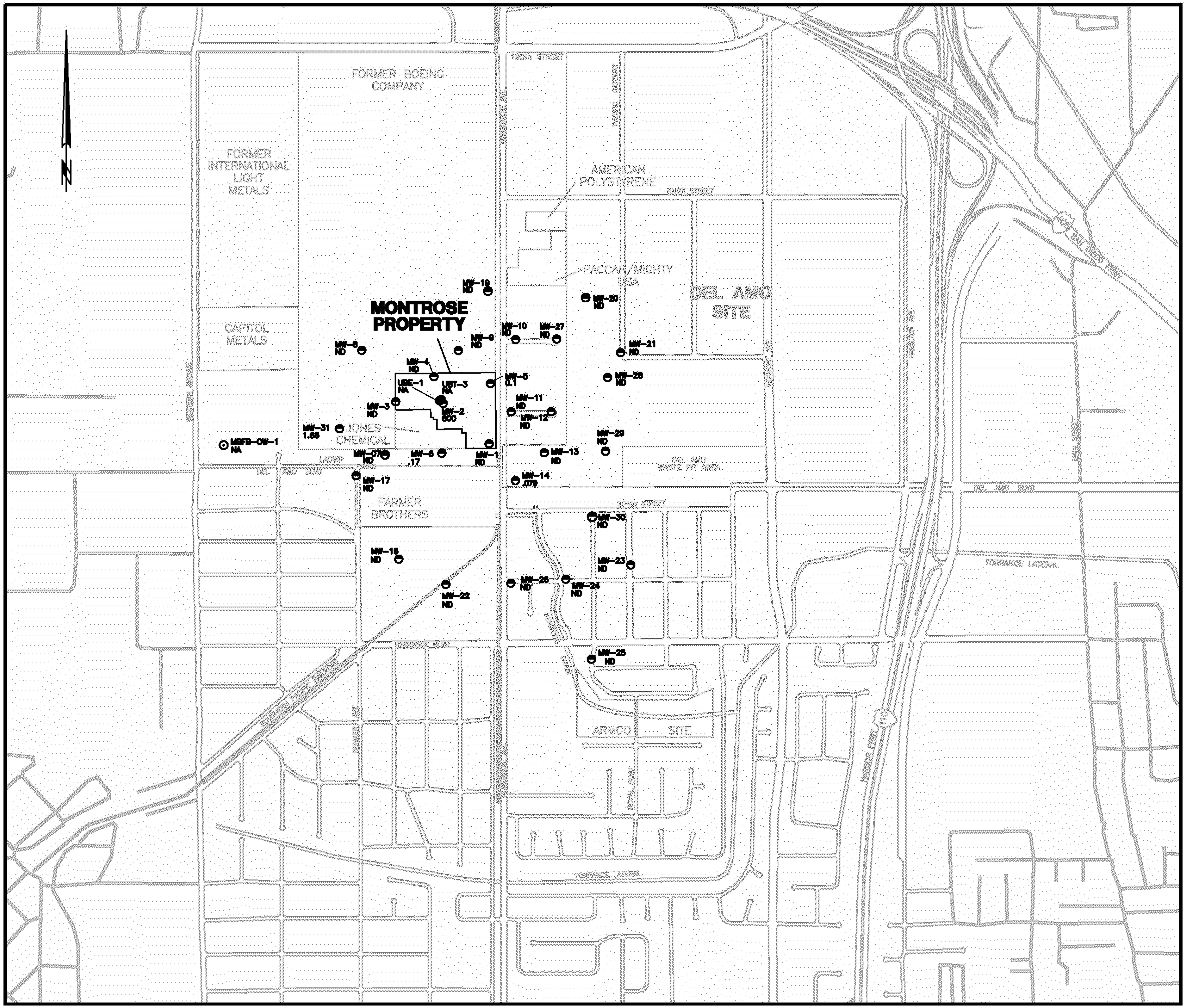
MCB IN GROUNDWATER
UPPER BELLFLOWER AQUITARD

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

04-09

FIGURE 2.20

RPT NO. 857.50d | 210-3277 | A



EXPLANATION

MW-5 0.1	UPPER BELLFLOWER AQUITARD MONITOR WELL TOTAL DDT CONCENTRATION MICROGRAMS PER LITER BASED ON SUM OF COMPONENT COMPOUNDS
MBFB-OW-1 NA	UPPER BELLFLOWER AQUITARD OBSERVATION WELL
NA	NOT ANALYZED
ND	NONE OF THE COMPONENT COMPOUNDS DETECTED IN THE SAMPLE
DDT	DICHLORODIPHENYLTRICHLOROETHANE

NOTE:
RESULTS SHOWN ARE FOR SAMPLES COLLECTED BETWEEN 1990 AND 2004. THE MOST RESENT RESULT IS SHOWN FOR EACH WELL SAMPLE.

SOURCE: HARGIS + ASSOCIATES, 2007a

0 1000 2000
FEET

MONTROSE CHEMICAL CORPORATION
TORRANCE, CALIFORNIA

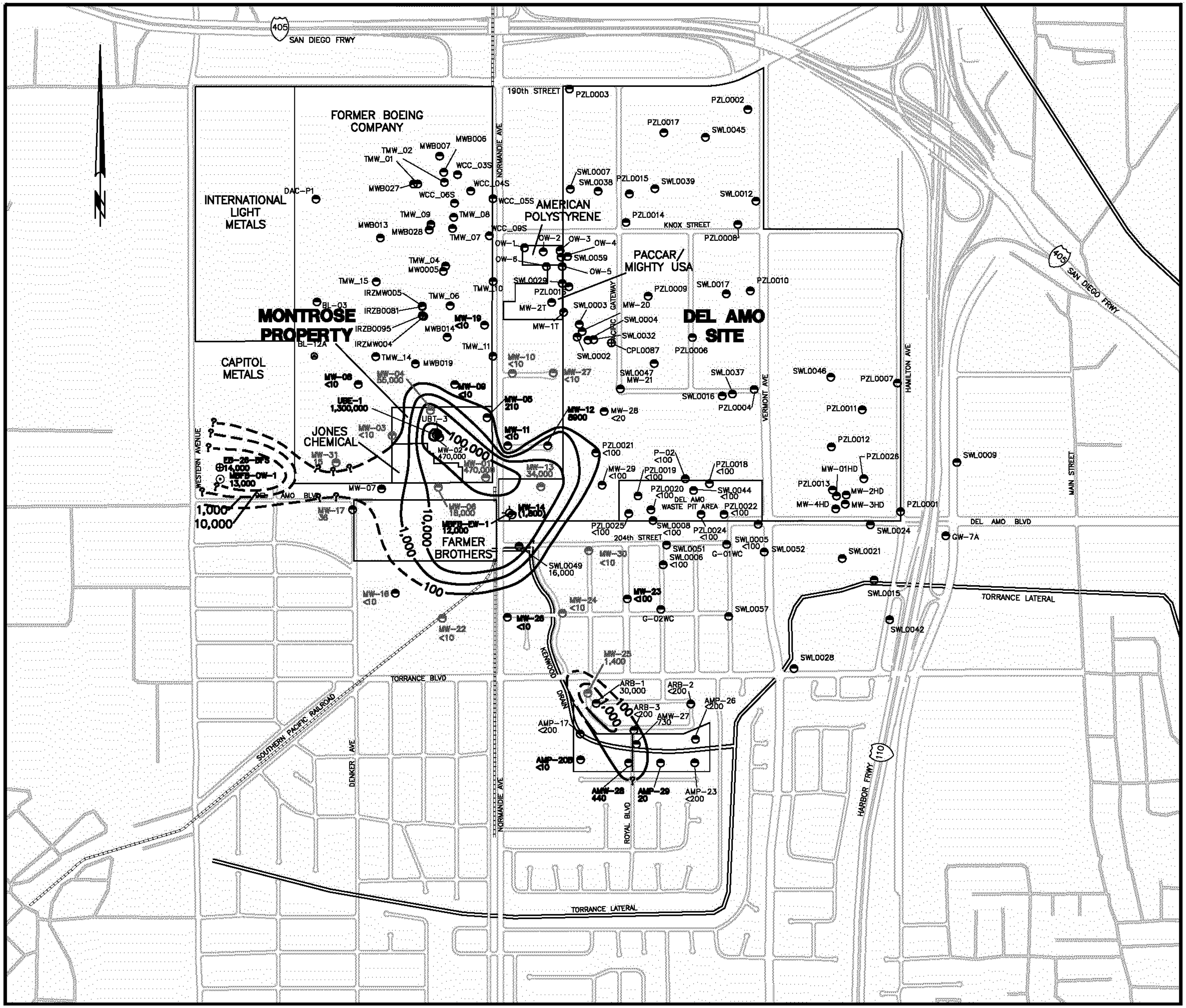
TOTAL DDT IN GROUNDWATER
UPPER BELLFLOWER AQUITARD

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

04-09

FIGURE 2.21

RPT NO. 857.04b | 210-3279 | A



EXPLANATION

MW-25	UPPER BELLFLOWER AQUITARD MONITOR WELL
1,400	CONCENTRATION IN MICROGRAMS PER LITER, COLLECTED OCTOBER 2006
MW-26	UPPER BELLFLOWER AQUITARD MONITOR WELL
<10	CONCENTRATION IN MICROGRAMS PER LITER, COLLECTED BETWEEN 2004 AND OCTOBER 2006
EB-28-BFS 14,000	EXPLORATORY BORING AND TEMPORARY UPPER BELLFLOWER AQUITARD MONITOR WELL
MBFB-EW-1 12,000	MIDDLE BELLFLOWER "B" EXTRACTION WELL
MBFB-OW-1 13,000	MIDDLE BELLFLOWER "B" OBSERVATION WELL
MW-28	UPPER BELLFLOWER AQUITARD MONITOR WELL
<20	CONCENTRATION IN MICROGRAMS PER LITER, COLLECTED PRIOR TO 2004
(1,800)	CONCENTRATION NOT CONTOURED

?———100—— ——?

CONTOUR LINE OF EQUAL CONCENTRATION OF pCBSA IN MICROGRAMS PER LITER
DASHED WHERE APPROXIMATE, QUERIED WHERE INFERRED
BASED ON MOST RECENT SAMPLING RESULT

< = LESS THAN; NUMERICAL VALUE IS THE LIMIT OF DETECTION FOR THIS CONSTITUENT.

WELL IDENTIFIER NOTES:

MW = MONTROSE MONITOR WELLS
MBFB = MONTROSE OBSERVATION WELLS
AMW, AMP, AND ARB = ARMCO MONITOR WELLS
G, GW, MW-HD, SWL, PZL, P AND MW-2T = DEL AMO MONITOR WELLS
DAC, TMW, WCC, MWB = BOEING MONITOR WELLS
BL = INTERNATIONAL LIGHT METALS MONITOR WELLS
OW = AMERICAN POLYSTYRENE MONITOR WELLS
IRZB, IRZMW = BOEING BIOREMEDIATION WELLS

SOURCE: HARGIS + ASSOCIATES, 2007a

0 1000 2000
FEET

MONTROSE CHEMICAL CORPORATION OF CALIFORNIA
TORRANCE, CALIFORNIA

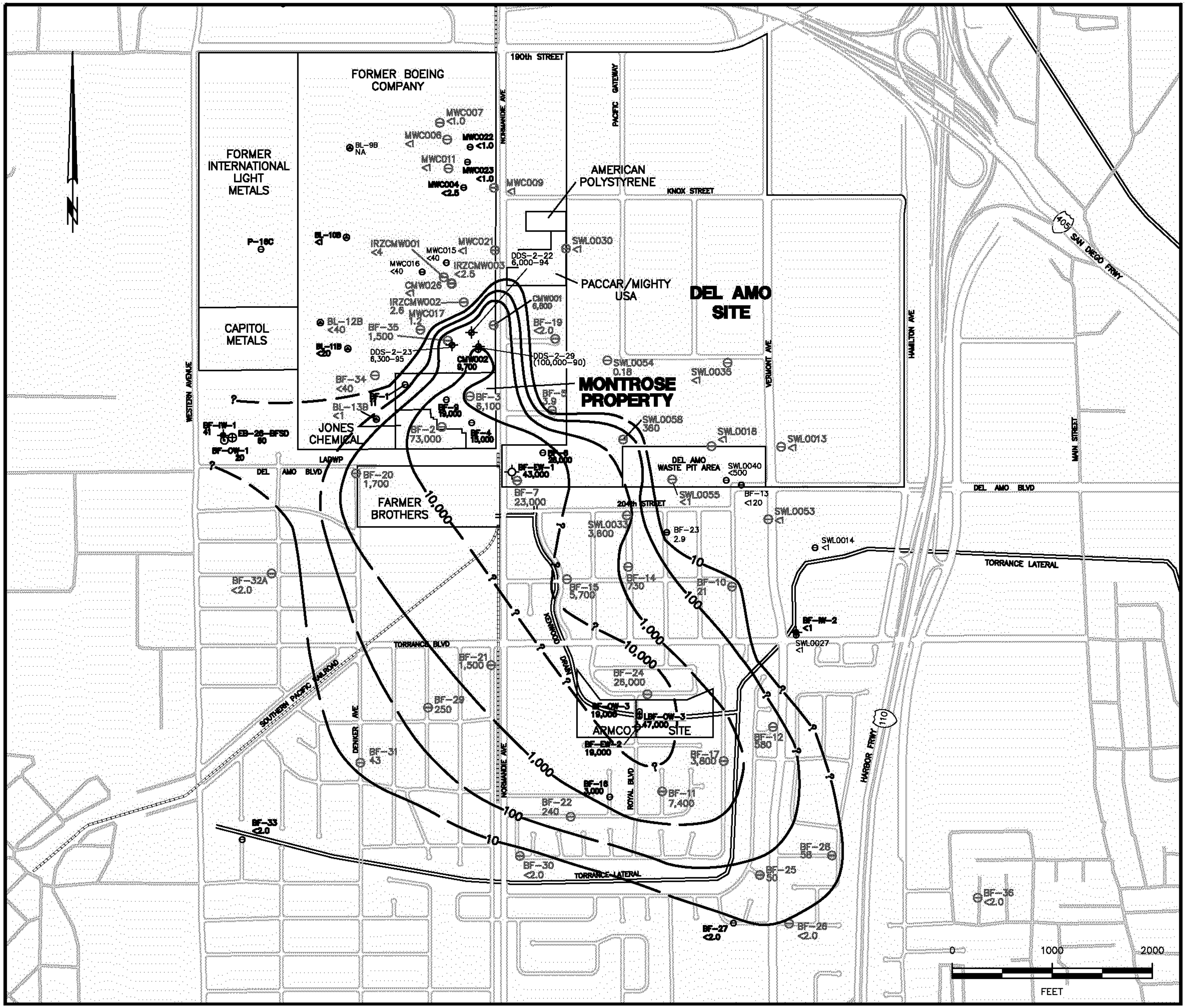
pCBSA IN GROUNDWATER
UPPER BELLFLOWER AQUITARD

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

04-09

FIGURE 2.22

RPT NO. 857.04b | 210-3274 | A



EXPLANATION

BF-28 ⊖ 58	BELLFLOWER SAND MONITOR WELL CONCENTRATION IN MICROGRAMS PER LITER, SAMPLED SEPTEMBER – NOVEMBER 2006
BF-15 ⊖ 8,300	BELLFLOWER SAND MONITOR WELL CONCENTRATION IN MICROGRAMS PER LITER, COLLECTED BETWEEN 2004 AND SEPTEMBER 2006
BF-23 ⊖ 2.9	BELLFLOWER SAND MONITOR WELL COLLECTED PRIOR TO 2004
BF-EW-1 43,000	BELLFLOWER SAND EXTRACTION WELL
BF-IW-1 41	BELLFLOWER SAND INJECTION WELL
BF-OW-3 19,000	BELLFLOWER SAND OBSERVATION WELL
EB-26-BFSD ⊕ 60	EXPLORATORY BORING AND TEMPORARY BELLFLOWER SAND MONITORING WELL
DDS-2-22 6,000-94	BOEING HYDROPUNCH SAMPLE LOCATION CONCENTRATION IN MICROGRAMS PER LITER SAMPLE COLLECTION DEPTH. SAMPLED PRIOR TO SEPTEMBER 2006
BL-10B	CLUSTER WELL
NA	NOT ANALYZED
(100,000)	CONCENTRATION NOT CONTOURED

?——100——?

CONTOUR LINE OF EQUAL CONCENTRATION OF CHLOROBENZENE IN MICROGRAMS PER LITER DASHED WHERE APPROXIMATE, QUERIED WHERE INFERRED BASED ON MOST RECENT SAMPLING RESULTS.

< = LESS THAN; NUMERICAL VALUE IS THE LIMIT OF DETECTION FOR THIS ANALYSIS.

WELL IDENTIFIER NOTES:
- BF = MONTROSE MONITOR WELLS
- SWL = DEL AMO MONITOR WELLS
- WCC, MWC, CMW = BOEING MONITOR WELLS
- IRZCMW = BOEING BIOREMEDIATION WELLS
- BL = INDUSTRIAL LIGHT METAL MONITOR WELLS

SOURCE: HARGIS + ASSOCIATES, 2007a

MONTROSE CHEMICAL CORPORATION OF CALIFORNIA
TORRANCE, CALIFORNIA

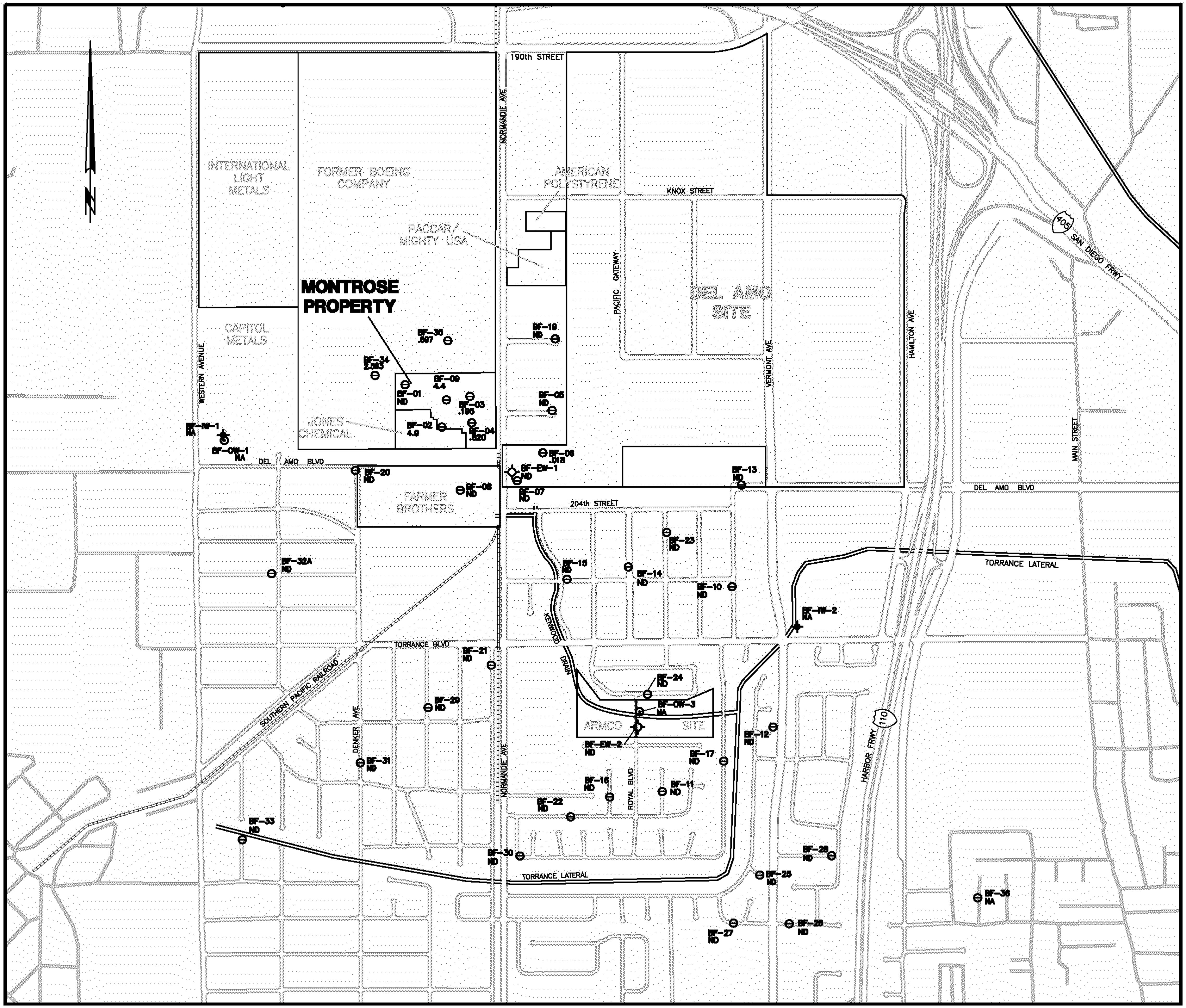
MCB IN GROUNDWATER BELLFLOWER SAND

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

04-09

FIGURE 2.23

RPT NO. 857.50e | 210-3276 | A



EXPLANATION

BF-05 ND	BELLFLOWER SAND MONITOR WELL CONCENTRATION IN MICROGRAMS PER LITER,
BF-EW-1 ND	BELLFLOWER SAND EXTRACTION WELL
BF-IW-1 NA	BELLFLOWER SAND INJECTION WELL
BF-OW-3 ND	BELLFLOWER SAND OBSERVATION WELL
NA	NOT ANALYZED
ND	NONE OF THE COMPONENT COMPOUNDS DETECTED IN THE SAMPLE

NOTE:
RESULTS SHOWN ARE FOR SAMPLES COLLECTED BETWEEN 1990 AND 2006. THE MOST RESENT RESULT IS SHOWN FOR EACH WELL SAMPLE.

SOURCE: HARGIS + ASSOCIATES, 2007a

0 1000 2000
FEET

MONTROSE CHEMICAL CORPORATION OF CALIFORNIA
TORRANCE, CALIFORNIA

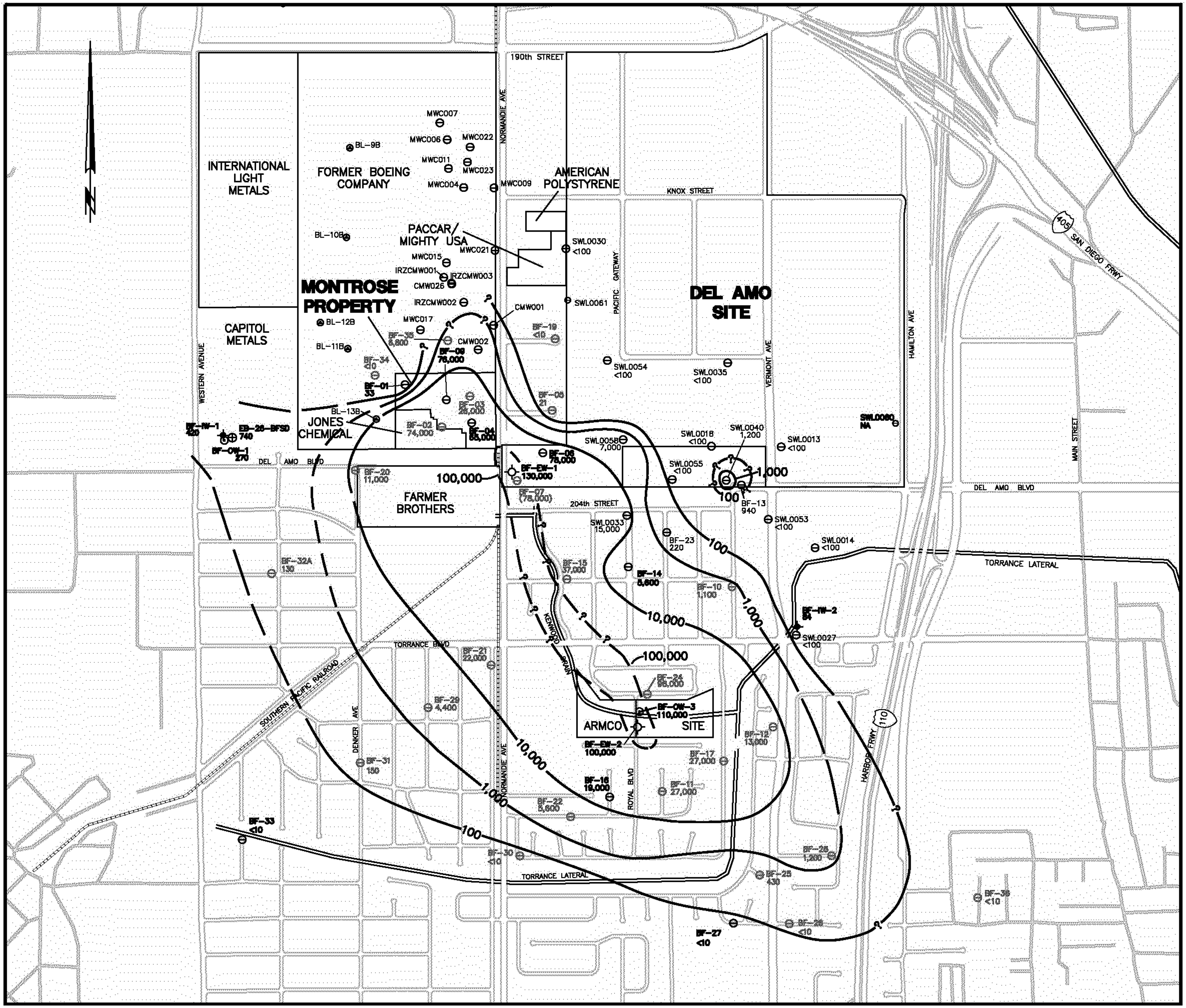
TOTAL DDT IN GROUNDWATER BELLFLOWER SAND

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

04-09

FIGURE 2.24

RPT NO. 857.04b | 210-3278 | A



EXPLANATION

BF-20 ⊖ 11,000	BELLFLOWER SAND MONITOR WELL CONCENTRATION IN MICROGRAMS PER LITER, COLLECTED OCTOBER 2006.
BF-05 ⊖ **18**	BELLFLOWER SAND MONITOR WELL CONCENTRATION IN MICROGRAMS PER LITER, COLLECTED BETWEEN 2004 AND OCTOBER 2006
SWL0040 ⊖ <100	BELLFLOWER SAND MONITOR WELL CONCENTRATION IN MICROGRAMS PER LITER, COLLECTED PRIOR TO 2004
BF-EW-1 130,000	BELLFLOWER SAND EXTRACTION WELL
BF-IW-1 420	BELLFLOWER SAND INJECTION WELL
BF-OW-3 110,000	BELLFLOWER SAND OBSERVATION WELL
EB-26-BFSD ⊕ 740	EXPLORATORY BORING AND TEMPORARY GAGE AQUIFER MONITOR WELL
BL-10B	CLUSTER WELL

?————100——— ——?

CONTOUR LINE OF EQUAL CONCENTRATION OF pCBSA IN MICROGRAMS PER LITER DASHED WHERE APPROXIMATE, QUERIED WHERE INFERRED BASED ON MOST RECENT SAMPLING RESULTS

< = LESS THAN; NUMERICAL VALUE IS THE LIMIT OF DETECTION FOR THIS ANALYSIS.

WELL IDENTIFIER NOTES:
BF = MONTROSE MONITOR WELLS
SWL = DEL AMO MONITOR WELLS
WCC, MWC, CMW = BOEING MONITOR WELLS
IRZCMW = BOEING BIOREMEDIATION WELLS
BL = INTERNATIONAL LIGHT METAL MONITOR WELLS

SOURCE: HARGIS + ASSOCIATES, 2007a

0 1000 2000
FEET

MONTROSE CHEMICAL CORPORATION OF CALIFORNIA
TORRANCE, CALIFORNIA

pCBSA IN GROUNDWATER BELLFLOWER SAND

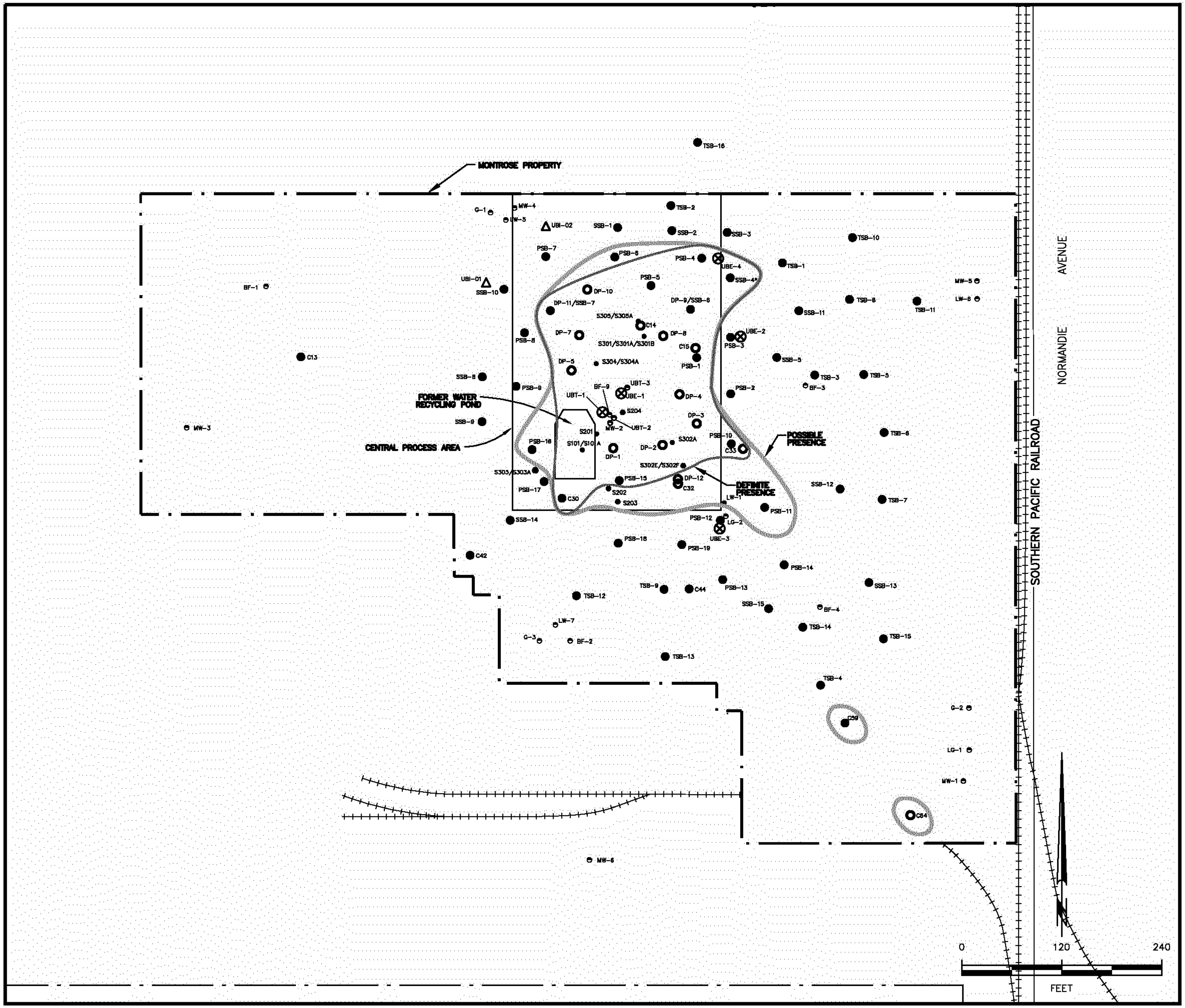
HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

04-09

FIGURE 2.25

RPT NO. 857.04b | 210-3275 | A

BOE-C6-0059713



EXPLANATION

- MUD ROTARY BORING DRILLED TO 2003
- DIRECT PUSH BORING DRILLED 2003
- SONIC BORING DRILLED 2003–2005
- MONITOR WELL
- EXTRACTION WELL
- INJECTION WELL
- DEFINITE DNAPL EXTENT IN UNSATURATED UBA
- POSSIBLE EXTENT IN UNSATURATED UBA

SOURCE: HARGIS + ASSOCIATES, 2006a

MONTROSE CHEMICAL CORPORATION
TORRANCE, CALIFORNIA

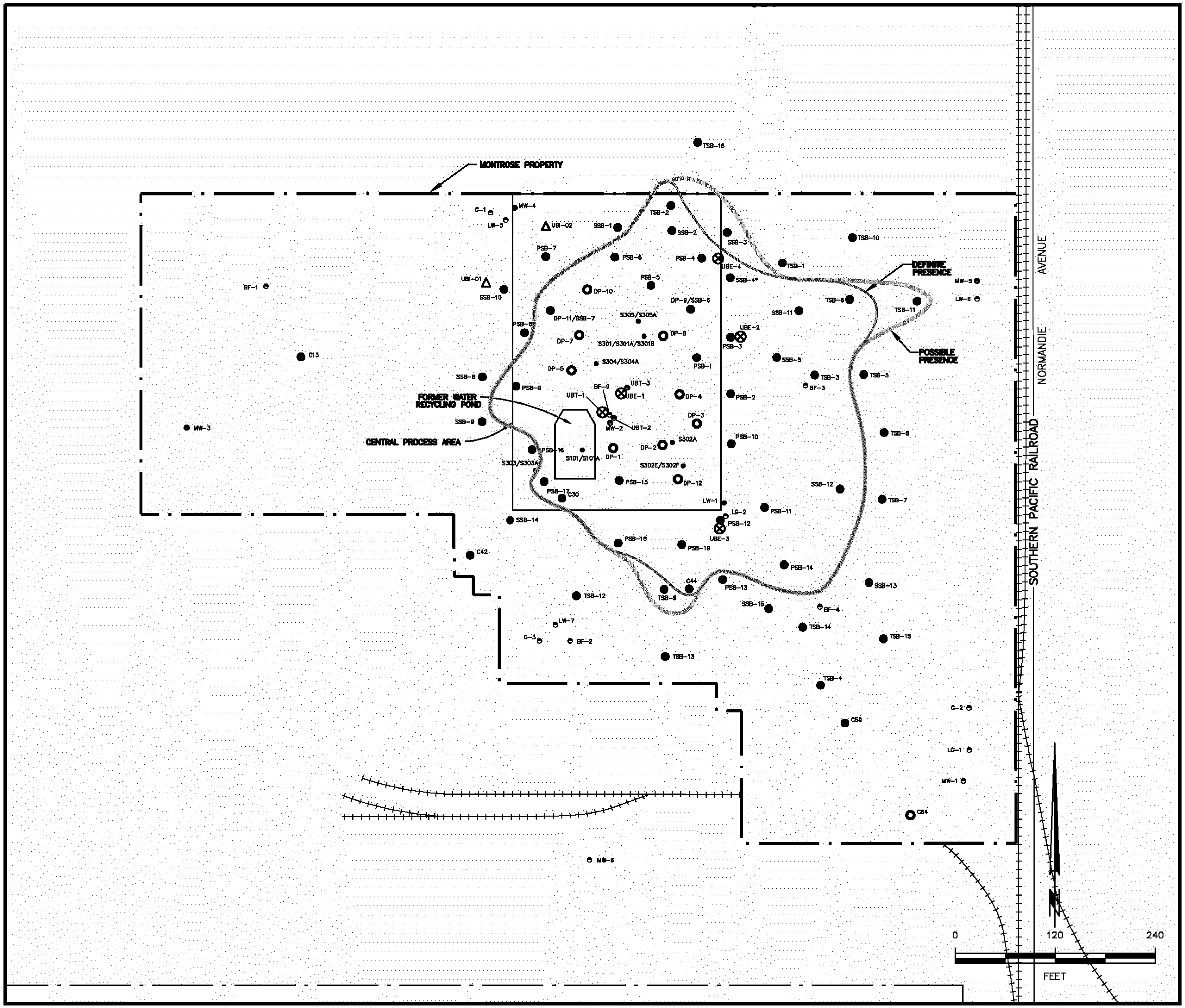
DNAPL EXTENT IN THE UNSATURATED UBA (0-60 FEET bgs)

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

04-09

FIGURE 2.26

RPT NO. 857.04b | 410-6615 | A



EXPLANATION

- MUD ROTARY BORING DRILLED PRIOR TO 2003
- DIRECT PUSH BORING DRILLED 2003
- SONIC BORING DRILLED 2003–2005
- MONITOR WELL
- EXTRACTION WELL
- INJECTION WELL
- DEFINITE DNAPL EXTENT IN SATURATED UBA
- POSSIBLE DNAPL EXTENT IN THE SATURATED UBA

SOURCE: HARGIS + ASSOCIATES, 2006a

MONTROSE CHEMICAL CORPORATION
TORRANCE, CALIFORNIA

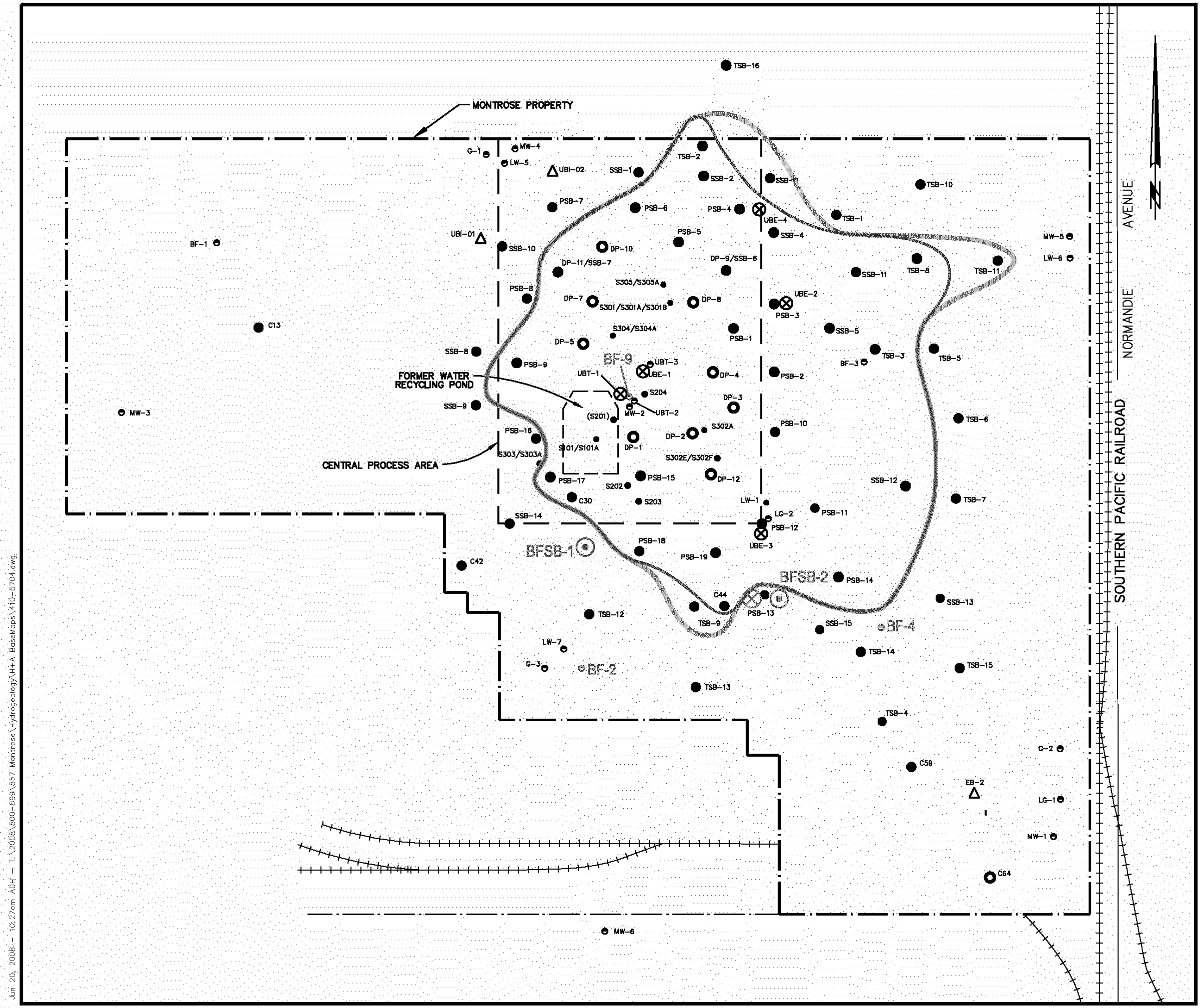
DNAPL EXTENT IN THE SATURATED UBA (60-105 FEET bgs)

HARGIS+ASSOCIATES, INC.
Hydrogeology/Engineering

04-09

FIGURE 2.27

RPT NO. 857.04b	410-6616	A



EXPLANATION

BFSB-1	BELLFLOWER SAND DNAPL RECONNAISSANCE BORING AND DEPTH DISCRETE GROUNDWATER SAMPLE LOCATION, APRIL–MAY 2006
	INITIAL LOCATION OF BORING BFSB-2, ABANDONED AND RELOCATED AS SHOWN
BF-2	DEPTH DISCRETE GROUNDWATER SAMPLE LOCATION, MARCH 2008
S305/S305A	SOIL BORING
MW-2	MONITOR WELL
PSB-7	SONIC BORING
DP-10	DIRECT PUSH BORING
UBE-2	EXTRACTION WELL
UBI-01	INJECTION WELL
	PROPERTY BOUNDARY
	DEFINITE DNAPL EXTENT IN SATURATED UBA
	POSSIBLE DNAPL EXTENT IN THE SATURATED UBA

SOURCE: HARGIS + ASSOCIATES, 2008c

BFS = BELLFLOWER SAND

NOTE: FIGURE ORIGINALLY PRODUCED AS PART OF THE RESULTS OF THE DNAPL RECONNAISSANCE INVESTIGATION: HARGIS + ASSOCIATES, INC., 2004. RESULTS OF DNAPL RECONNAISSANCE INVESTIGATION, MONTROSE SITE, TORRANCE, CALIFORNIA, JUNE 19, 2004. FIGURE SUBSEQUENTLY MODIFIED BASED ON DATA COLLECTED AS PART OF THE SUPPLEMENTAL SOILS INVESTIGATION IN TECHNICAL MEMORANDUMS TITLED: DNAPL RECONNAISSANCE BORINGS IN SUPPORT OF EARTH TECH SOIL SAMPLING PROGRAM. MONTROSE SITE, TORRANCE, CALIFORNIA. JANUARY 19, 2006; AND, ADDENDUM 2 TO THE RESULTS OF DNAPL RECONNAISSANCE INVESTIGATION, MONTROSE SITE, TORRANCE, CALIFORNIA, FEBRUARY 20, 2008.

0 100 200
FEET

MONTROSE CHEMICAL CORPORATION OF CALIFORNIA
TORRANCE, CALIFORNIA

2008 DNAPL INVESTIGATION BORINGS, BFS

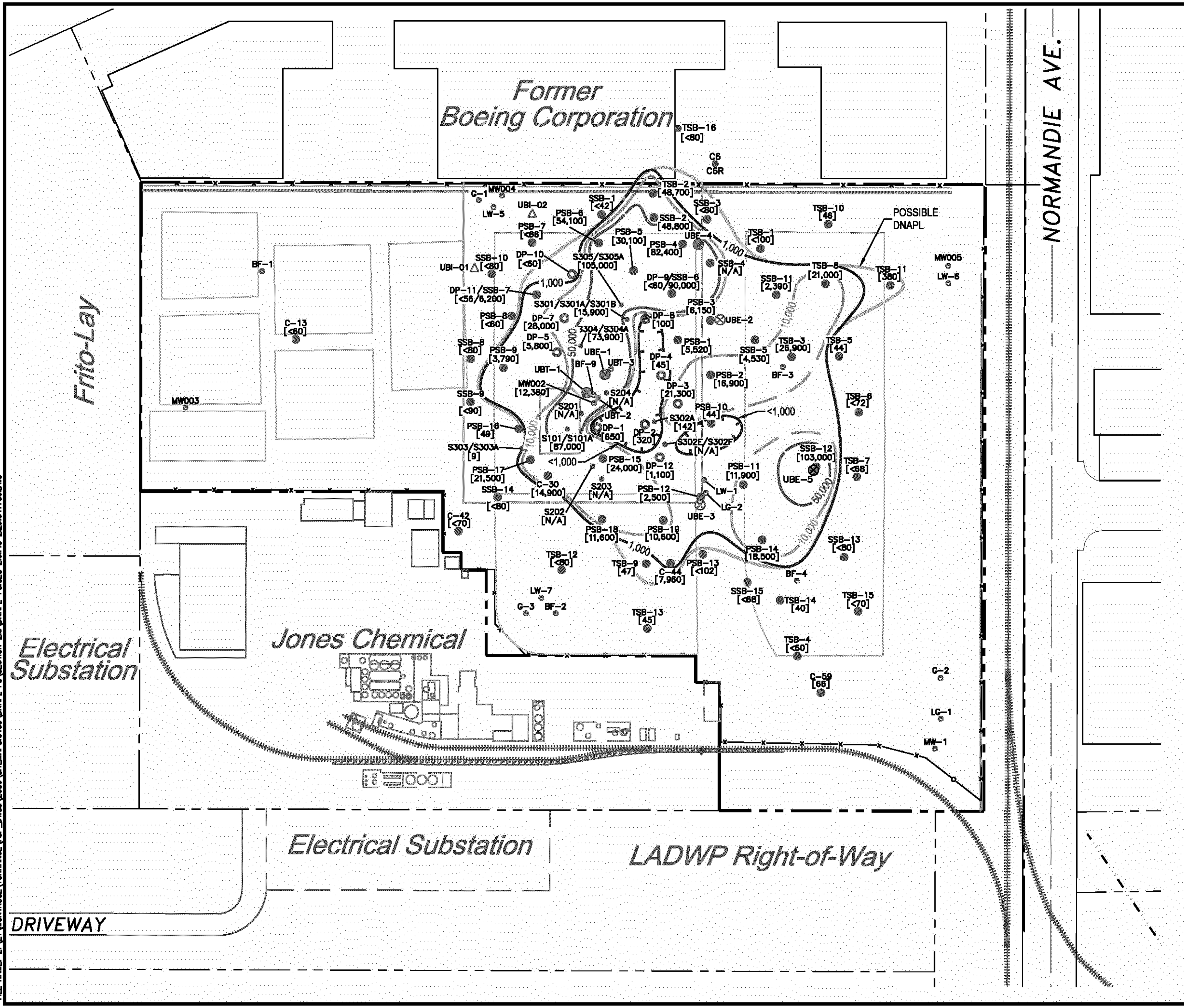
HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

04-09

FIGURE 2.28

RPT NO. 857.04G | 410-6704 | C

BOE-C6-0059716



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- PSB-7 — Sonic Boring Location
- DP-10 — Direct Push Boring Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- Entire Possible DNAPL Impacted Area
- 1,000 — 1,000 mg/kg DNAPL Concentration (MCB + Total DDT)
- 10,000 — 10,000 mg/kg DNAPL Concentration (MCB + Total DDT)
- 50,000 — 50,000 mg/kg DNAPL Concentration (MCB + Total DDT)
- [21,000] — MCB + Total DDT mg/kg

References:

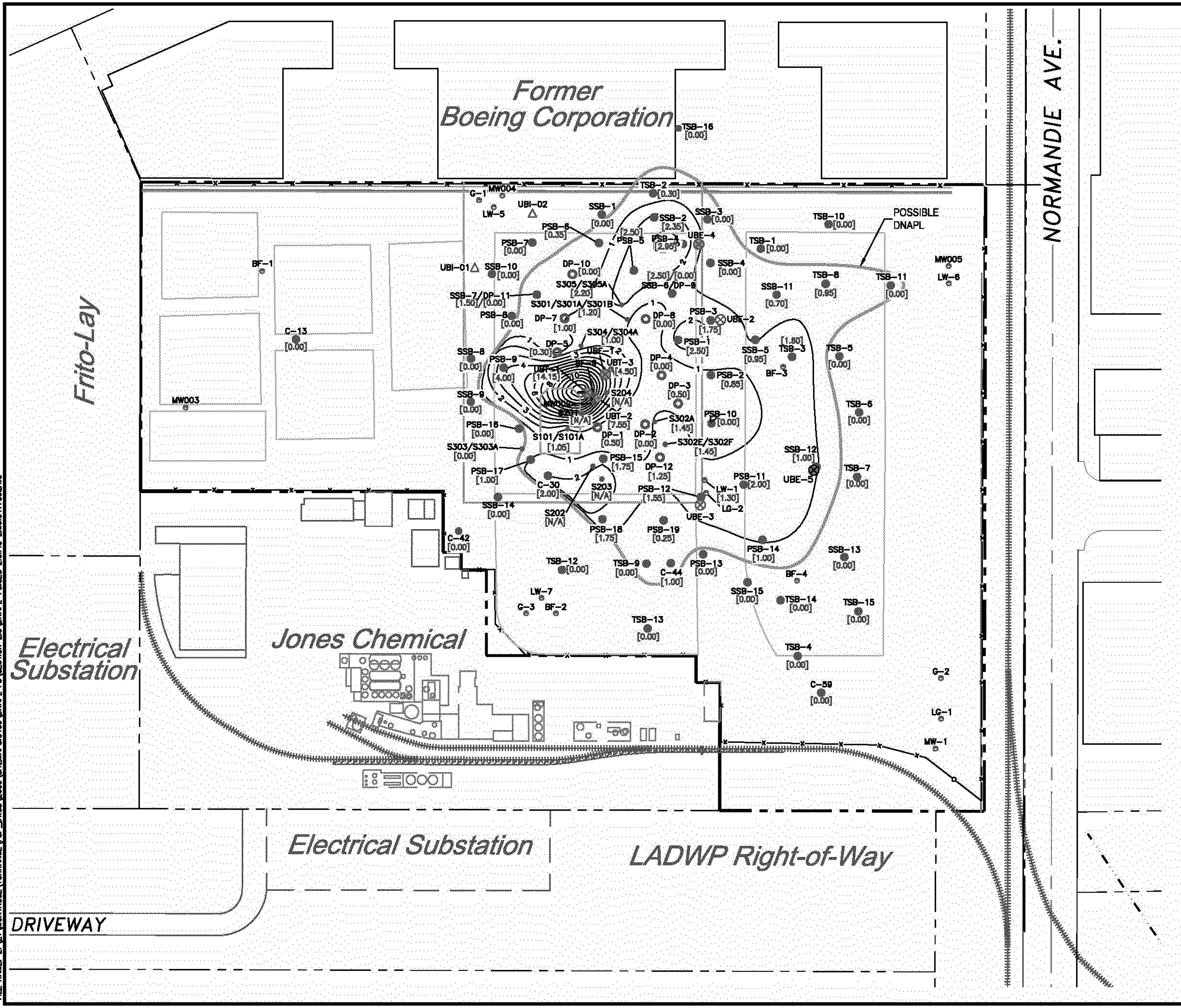
1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, On-line ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. Source: Earth Tech, 2008b

Montrose Chemical Corporation

Maximum DNAPL Concentration, Saturated UBA

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	2.29

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS 0409\DNAPL FS\SECTION 2.0\DNAPL-FS SEC 2.0 FIG 2.29 041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- PSB-7 — Sonic Boring Location
- DP-10 — Direct Push Boring Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- Entire Possible DNAPL Impacted Area
- 1 — DNAPL Definite Thickness in Feet
- [1.60] — DNAPL Thickness in Feet

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, On-line ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. Source: H+A, 2008a

Montrose Chemical Corporation		
Liberal DNAPL Thickness, Saturated UBA		
Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	2.30

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 2.0\DNAPL-FS.SEC 2.0.FIG 2.30.041709.DWG

Section 3.0

Remedial Action Objectives, General Response Actions and ARARS

3.0 REMEDIAL ACTION OBJECTIVES, GENERAL RESPONSE ACTIONS, and ARARS

This section identifies the objectives and regulatory requirements for the remedial alternatives considered by this DNAPL FS. The first step is to identify RAOs for protecting human health and the environment, which will be used throughout the screening process. Following development of RAOs for the Site, GRAs are defined which are actions that may achieve the RAOs. During the screening process (Section 4.0), remedial technologies, process options, and alternatives that are not capable of meeting the RAOs will be eliminated. Compliance with ARARs must also be considered throughout the screening process; thus an overview of ARARs developed for the Site is presented. Together, the development of RAOs, GRAs, and ARARs will provide a basis for the selection of applicable treatment technologies and remedial action alternatives to be evaluated during the screening process.

3.1 REMEDIAL ACTION OBJECTIVES

Remedial alternatives must satisfy the fundamental goal of being protective of human health and the environment. RAOs have been developed for DNAPL that will satisfy this goal and incorporate the contaminants of concern (COCs), potential receptors, potential exposure routes, and acceptable exposure levels. EPA found that it is technically impracticable to reduce contaminant concentrations within the DNAPL-impacted zone to pre-defined Maximum Contaminant Levels (MCLs) or risk-based cleanup levels (as defined in the Groundwater ROD, EPA, 1999). For this reason, a TI Waiver Zone was established in the Groundwater ROD throughout the DNAPL-impacted soils, and long-term hydraulic containment of contaminants within the TI Waiver Zone are required by that ROD. Therefore, the generalized objectives for remediation within the DNAPL-impacted zone are to remove DNAPL mass to the extent practicable, to reduce the mobility of DNAPL in the subsurface, and to decrease the uncertainty associated with the groundwater remedy and containment requirements. As a result, RAOs for DNAPL are more appropriately specified in terms of contaminant mobility and mass reduction than they would be in terms of contaminant concentrations. Accordingly, the RAOs for DNAPL at the Site are as follows:

1) Prevent human exposure to DNAPL constituents (via ingestion, inhalation, or dermal contact) that would pose an unacceptable health risk to on- or off-property receptors under industrial land uses of the Montrose plant property and adjacent properties;
2) To the extent practicable, limit uncontrolled lateral and vertical migration of mobile NAPL under industrial land use and hydraulic conditions in groundwater;
3) Increase the probability of achieving and maintaining containment of dissolved-phase contamination to the extent practicable, as required by the existing groundwater ROD, for the time period that such containment remains necessary;

4) Reduce NAPL mass to the extent practicable;
5) To the extent practicable, reduce the potential for recontamination of aquifers that have been restored by the groundwater remedial actions, as required by the groundwater ROD, in the event containment should fail; and
6) To the extent practicable, reduce the dissolved-phase concentrations within the containment zone over time.

The above RAOs were established for the DNAPL program following a series of technical meetings with EPA in 2007 and 2008, with the final RAOs established at a September 11, 2008 meeting.

3.2 GENERAL RESPONSE ACTIONS

GRAs are remedial technologies and associated process options that may achieve the RAOs for protecting human health and the environment. Protectiveness can be achieved by reducing exposure or exposure routes, such as restricting access to DNAPL-impacted soils. Protectiveness can also be achieved by reducing the mass or mobility of DNAPL in the subsurface. The GRAs for DNAPL at the Site are identified according to the following seven general categories:

- No action
- Institutional controls
- Containment
- Collection/Extraction
- In-Situ Treatment
- Ex-Situ Treatment
- Disposal

A brief description of each GRA category is provided as follows:

- **No Action:** Under this GRA, no further action would be taken at the Site to remediate DNAPL beyond what is otherwise required for containment under the Groundwater ROD. The use of a no action alternative serves to establish a baseline by which the protectiveness of other remedies can be measured.

- **Institutional Controls:** Under this GRA, institutional controls include implementation of administrative procedures and access restrictions to prevent human exposure to DNAPL-impacted soils. Two examples of institutional controls are deed restrictions and fencing.

- **Containment:** Under this GRA, human health and the environment are protected by controlling the exposure pathways, specifically DNAPL impacts to groundwater. Hydraulic containment of DNAPL impacts to groundwater is required by the Groundwater ROD, and therefore, all remedial alternatives evaluated in this FS will assume that hydraulic containment, by groundwater extraction, is implemented within the DNAPL-impacted zone as part of the groundwater remedy.

- **Collection/Extraction:** This GRA includes methods for extracting DNAPL from contaminated media for ex-situ treatment or disposal. Primary collection methods for DNAPL include soil vapor extraction (for VOC component present above the water table), passive extraction (i.e. extraction of DNAPL into wells), and active extraction (i.e. hydraulic displacement). Enhanced collection methods for DNAPL include injection of a surfactant/polymer, to enhance DNAPL mobility, and flooding with a co-solvent, such as an alcohol.

- **In-Situ Treatment:** This GRA involves treating contaminated media in-situ by changing the physical or chemical state of the contaminant. In-situ treatment methods for DNAPL include biological degradation, chemical oxidation, and thermal remediation, the latter of which can result in contaminant volatilization, oxidation, or flushing. Under this GRA, the need for ex-situ treatment or disposal of contaminants may be reduced or eliminated.

- **Ex-Situ Treatment:** This GRA includes ex-situ technologies for treatment of contaminants from a collection process. Ex-situ treatment technologies for soil vapors include thermal oxidation and adsorption, using either disposable or steam-regenerable carbon or resin. The ex-situ treatment technologies for groundwater, as identified by the Groundwater ROD, include liquid-phase granular activated carbon (LGAC) and advanced oxidation. The only ex-situ treatment technology considered for DNAPL is separation (from groundwater), and disposal of the separated DNAPL off-Site.

- **Disposal:** This GRA includes disposal options for contaminants from a collection process. Disposal options for groundwater include re-injection into the DNAPL-impacted zone (saturated UBA) or into the BFS and Gage Aquifer in coordination with the groundwater remedy. In accordance with the groundwater ROD, only treated groundwater can be re-injected into the BFS and Gage Aquifer. However, for the DNAPL-impacted UBA, re-injection of both treated and untreated groundwater is considered in this FS at the recommendation of EPA. The disposal option for collected DNAPL is off-Site incineration.

The above GRAs are further discussed and preliminarily evaluated against three performance criteria in Section 4.0. The extent of DNAPL (area and volume) for which these GRAs are being evaluated is presented in Section 2.0. Additional details regarding treatment areas, volumes, and flow rates are provided in Section 5.0 for GRAs retained following the preliminary evaluation and assembled into remedial alternatives.

3.3 ARARS

The Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986, promulgated cleanup standards at Superfund sites, 42 USC §§ 9610-9675. CERCLA requires that remedial actions meet federal standards that are determined to be applicable or relevant and appropriate (42 USC § 9621(d), CERCLA § 121(d)). The terms "*Applicable*" and "*Relevant and Appropriate*" are defined in the Code of Federal Regulations (CFR), Title 40, Section 300.5. An "*Applicable*" requirement refers to those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a CERCLA site. A "*Relevant and Appropriate*" requirement refers to cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law. Non-promulgated advisories or guidance issued by Federal or State government that are not legally binding and do not have the status of potential ARARs can additionally be considered for remedial action, and these criteria are conventionally referred to as "*To Be Considered*" (TBCs). Applicable standards are those that apply directly to site circumstances or condition and require little judgment in determining suitability. If the requirement is not applicable, it may nonetheless be relevant and appropriate if, based on best professional judgment, the circumstances or conditions at the CERCLA site are sufficiently similar to the conditions addressed by the requirement.

ARARs are subdivided into three categories as follows:

- Chemical-Specific ARARs: Requirements that set health- or risk-based concentration limits or discharge limitations on specific chemicals released into the environment.
- Action-Specific ARARs: Requirements that govern performance, design, or other similar criteria related to particular remedial actions (e.g. air emission requirements).
- Location-Specific ARARs: Requirements that place restrictions on activities due to their particular locations (e.g. floodplains, faults, wetlands).

Additionally, only the substantive portions of state and federal environmental laws and regulations are ARARs for remedial actions at the Property. Under CERCLA, "administrative requirements", such as administration of permits, are not considered ARARs, although in practice, general requirements on a local level are typically followed.

Identification of the ARARs and TBCs for DNAPL was accomplished by reviewing federal, state, and local laws, regulations, and policies. A determination of ARARs and TBCs was made based upon the terms of those statutes, regulations, and policies, consideration of EPA guidance, primarily the guidance entitled *CERCLA Compliance With Other Laws Manual: Interim Final (Parts I and II)*, EPA/540/G-89/006 (EPA, 1989b), and discussions with EPA. The ARARs and TBCs identified for DNAPL are listed below and summarized in **Table 3.1.** The applicability and relevance of these ARARs is not discussed in this section but is provided in Table 3.1.

Chemical-Specific ARARs

- Clean Water Act (CWA) or Federal Water Pollution Control Act (FWPCA) (33 USC §1251-1387) (40 CFR §100-149)
- Porter-Cologne Water Quality Control Act, California Water Code (§13140-13147, 13172, 13240, 13260, 13263, 13267, 13304, 13360) (27 CCR §20200-20230)
- State Water Resources Control Board Resolution 88-63, Los Angeles RWQCB Resolution 89-03
- South Coast Air Quality Management District, Permit Screening Emission Level for Chloroform (Package "L", Table 1A)

Location-Specific ARARs

- Migratory Bird Treaty Act (16 USC §703-712)
- Endangered Species Act of 1973 (16 USC §1531-1536) (50 CFR Part 17, 402)
- Executive Order on Flood Plain Management (Exec. Order No. 11,988) (40 CFR §6.302, App A)

Action-Specific ARARs

- State Water Resources Control Board Order 99-08-DWQ and Resolutions 68-16 and 92-49 III.G
- NPDES Non-Point Discharge (40 CFR §122.26)
- Identification and Characterization of Hazardous Waste (40 CFR §261 et seq.) (22 CCR §66261 et seq.)
- Solid Waste Disposal Act and Resource Conservation and Recovery Act (RCRA), Generators of Hazardous Waste (40 CFR §262 et seq.) (22 CCR §66262 et seq.)
- Land Disposal Restrictions (40 CFR §268 et seq.) (22 CCR §66268 et seq.)
- Waste Management and Classification (27 CCR §20200-20220)
- California Hazardous Waste Control Act, California Health & Safety Code (§25100, et seq.)
- Requirements for the Underground Injection Control Program (40 CFR §144-148)
- California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65), Health and Safety Code (§25249.5 et seq.) (22 CCR §12000)
- Clean Air Act (CAA) (42 USC §7401-7462) (40 CFR §60-69)
- South Coast Air Quality Management District (Rule 201.1, 401-405, 408, 409, 466, 474, 476, 1001, 1146, 1166, 1176, 1301, 1401)
- Land Use Covenant (22 CCR §67391.1)

- Environmental Covenant, California Civil Code (§1471)
- City and Municipal codes for electrical, plumbing, and construction

TBCs

- National Ambient Air Quality Standards under the Federal Clean Air Act (40 CFR §50.4-50.13)
- California Ambient Air Quality Standards (17 CCR §70100 et seq.)
- California Well Standards, Department of Water Resources Bulletins 74-90 and 74-81
- California Global Warming Solutions Act of 2006 (AB32), Health and Safety Code (§38500 et seq.)
- EPA Policy on Green Remediation, April 2008
- EPA, Region 9, Smart Energy Resources Guide, March 2008 (EPA/600/R-08/049)

Carbon dioxide is the primary greenhouse gas (GHG) emitted by power generation plants and fuel combustion. The amount of energy required to implement an RA is directly related to the amount of greenhouse gases emitted to the atmosphere during power generation, whether on-site (e.g., via boilers) or off-site (e.g., at power plants). Reducing or minimizing generation of greenhouse gases is a principal subject of current "green remediation" initiatives being implemented by both EPA nationally and by EPA Region 9 regionally. Region 9's Smart Energy Resources Guide (SREG) emphasizes that the "optimal phase in which to start considering these actions is during the Remedial Investigation/Feasibility Study (RI/FS) phase of a cleanup". Such early consideration of GHG emissions is prudent given that the RA selection process largely determines a cleanup's carbon footprint. Further, the California Global Warming Solutions Act of 2006 establishes aggressive targets for the reduction of greenhouse gas emissions within California. A large carbon footprint would frustrate California's statutory mandate to reduce GHG emissions.

In March 2009, EPA proposed mandatory federal GHG reporting regulations that are triggered by facilities emitting more than 25,000 metric tons of carbon dioxide per year, not including indirect emissions attributable to electricity usage (Docket No. EPA-HQ-OAR-2008-0508). Additionally, a new climate and energy bill was presented to the U.S. House of Representatives on April 1, 2009. The draft bill would establish a cap-and-trade program to cut U.S. greenhouse gas emissions, set a national renewable electricity standard, and create new energy efficient programs. The bill also proposes to establish a new National Climate Service, within the National Oceanic and Atmospheric Administration, to provide local governments with information on climate change and technical assistance. Additionally, in a proposed finding dated April 17, 2009, EPA concluded that greenhouse gases (including carbon dioxide) endanger the public health and welfare of current and future generations. If promulgated, these proposed measures may become ARARs in the future.

The following four potential ARARs relating to drinking water standards were excluded from the above list:

- Federal Primary Drinking Water Standards (40 CFR §141)
- California Primary Drinking Water Standards (22 CCR §64431 and 64444)
- California Secondary Drinking Water Standards (22 CCR §64449)
- California Department of Health Applied Action Levels

The Groundwater ROD for the Site (EPA, 1999) established a TI Waiver Zone in which the requirements associated with these ARARs are waived due to technical impracticability. Since the DNAPL occurs fully within the TI Waiver Zone as described in Section 1.7, then the requirements associated with the above drinking water standards are not applicable and are therefore excluded from this FS. However, if groundwater generated by a DNAPL remedy is re-injected outside of the TI Waiver Zone boundaries, these ARARs would be applicable as would the In-Situ Groundwater Standards (ISGS) established in the Groundwater ROD.

TABLES

Table 3-1
DNAPL ARARs and TBCs
Montrose Superfund Site

Authority	Citation	Synopsis of Requirement	Action to be Taken to Attain Requirement	Applicable	Relevant and Appropriate	TBC	Remedial Alternative
CHEMICAL SPECIFIC ARARs							
Clean Water Act (CWA) or Federal Water Pollution Control Act (FWPCA)	33 USC §1251-1387, 40 CFR §100-149	Specifies standards and requirements for all water programs for discharge of any substances into any body of water and may be applicable to discharges to surface water.	Any DNAPL remedial alternatives with discharge to the storm water system would be required to comply with this ARAR. The selected remedy will meet the requirements to ensure that discharges do not cause a violation of surface water quality standards.		X		RAs 1-6A
	40 CFR §129	Regulates the discharge of certain chemicals, including DDT into navigable waters. Establishes effluent standards and prohibitions for discharge of toxic pollutants to storm water and may be incorporated into an NPDES permit. 40 CFR §129.101 establishes a water criterion of 0.001 ug/L for DDT in navigable waters.	Discharge of treated groundwater to the storm water system under an NPDES permit is a possible groundwater disposal option for DNAPL remedial alternatives. Any DNAPL remedial alternatives with discharge to the storm water system under an NPDES permit would be required to comply with this ARAR.		X		RAs 1-6A
Porter-Cologne Water Act (CWA), California Water Code	California Water Code §13140-13147, 13172, 13240, 13260, 13263, 13267, 13304, 13360 27 CCR §20200-20230	These provisions establish a classification system for solid wastes that cannot be discharged directly or indirectly to waters of the State, and instead, must be discharged to waste management units. Wastes classified as a threat to water quality (designated waste) may be discharged to a Class I hazardous waste or Class II designated waste management unit. Non-hazardous solid waste may be discharged to a Class I, II, or III waste management unit. Inert waste would not be required to be discharged into a SWRCB-classified waste management unit. Establishes water quality objectives, including narrative and numerical standards and establishes implementation plans to meet objectives and protect beneficial uses. Incorporates state-wide water quality control plans and policies.	Solid wastes not meeting cleanup criteria will be classified for disposal to appropriate permitted off-site waste management units. Candidate DNAPL remedial alternatives that generate wastes that cannot be discharged to waters of the State will need to comply with these ARARs.		X		RAs 1-6A
State Water Resources Control Board (SWRCB) Order 88-63	State Water Resources Control Board Order 88-63, Los Angeles Resolution 89-03 (adopting Resolution 88-63 into Basin Plan)	This resolution has been incorporated into all Regional Board Basin Plans. This policy specifies that ground and surface waters of the state are either existing or potential sources of municipal and domestic supply except water supplies with: (a) Total dissolved solids exceeding 3,000 milligrams per liter, or (b) Natural or anthropogenic contamination (unrelated to a specific pollution incident) that cannot reasonably be treated for domestic use using either best management practices (BMPs) or best economically achievable treatment practices, or (c) The water source does not provide a sustained yield of 200 gallons per day.	Protection of groundwater quality is a fundamental objective for DNAPL remedial alternative evaluation, and restoration of groundwater quality was the subject of the Groundwater ROD (EPA, 1999). DNAPL-impacted saturated zones at the Montrose Site are not exempt from this order based on total dissolved solids, natural or anthropogenic contamination, or yield. This policy will be considered during evaluation of candidate DNAPL remedial alternatives.		X		RAs 1-6A
South Coast Air Quality Management District (SCAQMD), Permit Screening Emission Level for Chloroform	SCAQMD Permit Application Package "L", Table 1A	SCAQMD has established screening emission levels for various toxic air contaminants to determine if a screening risk assessment should be performed. The screening emission levels for chloroform, at three distances from the emission source, are as follows (may vary based upon cumulative health risk of all toxic air contaminants being emitted): 25 Meters: 6.24 pounds per year 50 Meters: 16.36 pounds per year 100 Meters: 48.75 pounds per year	Chloroform is a site-related VOC that may be generated by candidate DNAPL remedial alternatives. Alternatives that generate chloroform would require an assessment of emissions in comparison to these screening levels to determine if a more detailed screening risk assessment would be required under SCAQMD Rule 1401.	X			RAs 3-6A

Table 3-1
DNAPL ARARs and TBCs
Montrose Superfund Site

Authority	Citation	Synopsis of Requirement	Action to be Taken to Attain Requirement	Applicable	Relevant and Appropriate	TBC	Remedial Alternative
LOCATION SPECIFIC ARARs							
Migratory Bird Treaty Act	Title 16 USC §703-712	Except as permitted by regulations, it is unlawful to pursue, hunt, take, capture, offer to sell, barter, purchase, or deliver any migratory bird, nest, or egg.	No migratory birds, nests, or eggs are present at the Site; however, these regulations would be applicable if migratory birds were discovered at the site during DNAPL remedy implementation.		X		RAs 1-6A
Endangered Species Act of 1973; Protection of Endangered and Threatened Species	Title 16 USC §1531-1536; 50 CFR §17 and 402	Requires action to conserve endangered species and critical habitats upon which endangered species depend. Includes consultation with the Dept. of the Interior. Activities at all remedial sites must be performed in such a manner as to identify the presence of and protect endangered or threatened plants and animals at the site.	Remedial actions should avoid disturbance of terrain which is habitat for endangered species. No currently known endangered species are present at the site; however, these regulations will be considered and followed if endangered or threatened species are discovered.		X		RAs 1-6A
Executive Order on Flood Plain Management	Exec. Order No. 11988; 40 CFR §6.302 and Appendix A	Remedial actions occurring in a floodplain should avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values. Federal agencies are directed to ensure that planning programs reflect consideration of floodplain management.	This regulation will be relevant and appropriate if the area where the remedial action will occur is determined to be in a floodplain.		X		RAs 1-6A
ACTION SPECIFIC ARARs							
State Water Resources Control Board (SWRCB)	State Water Resources Control Board Order 99-08-DWQ	Must identify the sources of sediment and other pollutants that affect the quality of storm water discharges and implement practices to reduce these discharges. Storm water discharges from construction sites must meet pollutant limits and standards. The SWRCB has not established numeric effluent limitations. The narrative effluent standard includes the requirements to implement Best Available Technology Economically Achievable or Best Conventional Pollutant Control Technology to reduce or eliminate storm water pollution. The SWRCB adopted a statewide General Permit that applies to all storm water discharges associated with construction activity, excluding those covered by an individual site NPDES permit. The General Permit authorizes the discharge of storm water to surface waters from construction activities that result in disturbance of one or more acres of land. Construction activities subject to the General Permit including clearing, grading, excavation, or stockpiling.	DNAPL remedial alternatives must limit discharges to the storm water system during DNAPL remedy construction activities in accordance with this ARAR. The substantive portions of the State General Permit would be applicable to DNAPL remedies involving construction activities at the Site.	X			RAs 3-6A
	Resolution No. 68-16 Statement of Policy with Respect to Maintaining High Quality of Waters in California; Water Code §13140	State Anti-degradation Policy sets forth in State Board Resolution No. 68-16, which has been incorporated into all Regional Board Basin Plans. The resolution requires protection of the existing quality of water whenever it is better than that necessary to protect present and potential beneficial uses. Applies to the discharge of waste to waters, including re-injection into the aquifer.	A Technical Impracticability (TI) Waiver Zone was established for groundwater underlying the Montrose Site by EPA in the 1999 Groundwater ROD. Outside the TI Waiver Zone, groundwater would require treatment in compliance with the SWRCB provisions. Within the TI Waiver Zone, groundwater would require treatment in compliance with the conditions established by EPA for the TI Waiver Zone as indicated in the Groundwater ROD.		X		RAs 1-6A
	Resolution No. 92-49 III.G 23 CCR §2550.4 Background Water Quality; Policy and Procedures for Investigation and Cleanup and Abatement of Discharges under Water Code §13304 (amended 4/21/94)	To protect groundwater, the resolution requires cleanup to either background water quality or the best water quality that is reasonable if background water quality cannot be restored. Non-background cleanup levels must be consistent with maximum benefit to the public, present and anticipated future beneficial uses, and conform to water quality control plans and policies.	Restoration of groundwater quality associated with the Montrose Site was addressed by the Groundwater ROD (EPA 1999). A TI Waiver Zone was established for groundwater underlying the Site and extends beyond the extents of DNAPL impacts to soils. These regulations will be considered in connection with the DNAPL-impacted containment zone and TI Waiver Zone.		X		RAs 1-6A

Table 3-1
DNAPL ARARs and TBCs
Montrose Superfund Site

Authority	Citation	Synopsis of Requirement	Action to be Taken to Attain Requirement	Applicable	Relevant and Appropriate	TBC	Remedial Alternative
Code of Federal Regulations NPDES Stormwater Discharge	40 CFR §122.26	An NPDES permit is required for discharges composed entirely of stormwater if the discharge is associated with construction activities on sites that are between one and five acres, or any other construction activity that is deemed to have the potential for contribution to a violation of a water quality standard, or for a significant contribution of pollutants to the waters of the United States.	If the area where construction activities associated with the selected remedy will take place is between one and five acres, or is otherwise deemed to have the potential to violate water quality standards or significantly contribute pollutants to the waters of the U.S., then this ARAR is relevant and appropriate and any stormwater discharges will comply with the substantive requirements of any applicable permit.		X		RAs 3-6A
Code of Federal Regulations and California Code of Regulations Identification and Characterization of Hazardous Waste	40 CFR §261 et seq. 22 CCR §66261 et seq.	Defines wastes that are subject to regulation as a RCRA (or California) hazardous waste. Contaminated soil and groundwater (solid wastes), once extracted for treatment, must be managed as state and federal hazardous waste if such soil or groundwater contains levels of hazardous substances that meet or exceed state and federal hazardous waste toxicity criteria for specific hazardous wastes and/or contains one or more RCRA-listed hazardous wastes. 40 CFR §261.24 identifies waste containing >100 mg/L chlorobenzene as hazardous under the toxicity characteristic (waste code D021). 40 CFR 261.33 identifies waste containing DDT, as a discarded commercial product, as hazardous (waste code U061). In addition to federal hazardous waste standards, California also has specific state-regulated hazardous wastes. DNAPL exhibits the characteristic of "toxicity" if representative samples have: > 100.0 mg/L chlorobenzene by Toxicity Characteristic Leaching Potential (TCLP) > 1.0 mg/kg wet-weight DDT > 0.1 mg/L DDT by Soluble Threshold Limit Concentration (STLC)	These regulations establish provisions for characterizing wastes as hazardous (characteristic or by rule) and would be applicable to candidate DNAPL remedial alternatives which generate solid wastes. The determination of whether wastes generated during remedial activities are hazardous will be made at the time the wastes are generated. Some contaminated media treated to specified cleanup levels will no longer need to be managed as a hazardous waste; applicable to toxicity characteristic wastes (e.g., chlorobenzene, federal waste code D021).	X			RAs 3-6A
Solid Waste Disposal Act and Resource Conservation and Recovery Act (RCRA) Code of Federal Regulations and California Code of Regulations Generators of Hazardous Waste	40 CFR §262 et seq. 22 CCR §66262 et seq. Ch 12 incorporates by reference: • 49 CFR parts 172, 173, 178, and 179 • 40 CFR part 265, Subparts C, D, I, J, AA, BB, CC • 22 CCR Chapter 15, Articles 3, 4, 9, 10, 27, 28, and 28.5	DNAPL is a hazardous waste, and will be "generated", accumulated, and subsequently transported for off-site disposal. Under 42 USC §6901 et seq., RCRA mandates "cradle-to-grave" management of hazardous waste, and regulates three types of hazardous waste handlers: (1) generators, (2) transporters, and (3) owners and operators of treatment, storage, or disposal facilities (TSDFs). Only the substantive requirements of RCRA must be met if a CERCLA action is to be conducted on-site (do not require RCRA permits, nor compliance with the administrative requirements). Standards applicable to generators include requirements for waste determination, reporting, shipment, packaging, labeling, accumulation, documentation, and recordkeeping. In California, the State's promulgated regulations replace the equivalent Federal regulations as potential ARARs. See RCRA 3006(b), and 40 CFR §271. See Chapter 6.5 of H&S Code (HWCA), §25100 et seq.	Only the standards applicable to generators of hazardous waste apply to Montrose. Montrose will not transport hazardous waste or operate a TSDF. Candidate DNAPL remedial alternatives that generate hazardous waste would be subject to these ARARs.	X			RAs 3-6A

Table 3-1
DNAPL ARARs and TBCs
Montrose Superfund Site

Authority	Citation	Synopsis of Requirement	Action to be Taken to Attain Requirement	Applicable	Relevant and Appropriate	TBC	Remedial Alternative
Code of Federal Regulations and California Code of Regulations Land Disposal Restrictions	40 CFR §268 et seq., 22 CCR §66268 et seq.	Chapter 18 of both 40 CFR and 22 CCR identifies hazardous wastes that are restricted from land disposal and defines those limited circumstances under which an otherwise prohibited waste may continue to be land disposed. This chapter includes regulations governing various aspects of land disposal requirements, including waste analysis, treatment, and storage and recordkeeping. 22 CCR §66268.100 establishes land disposal prohibitions for non-RCRA hazardous wastes.	"Disposal" means: (a) the discharge, deposit, injection, dumping, spilling, leaking or placing of any waste or hazardous waste into or on any land or water so that such waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including groundwaters; (b) the abandonment of any waste. DNAPL remedial alternatives that generate hazardous wastes would be required to comply with the applicable provisions of these regulations. Land disposal restrictions would not be triggered if the media is treated to reduce contaminant concentrations in compliance with the treatment standards.	X			RAs 3-6A
California Code of Regulations Waste Management and Classification	27 CCR §20200-20220	Contains a waste classification system which applies to solid wastes that cannot be discharged directly or indirectly to waters of the state, and which therefore, must be discharged to waste management units (Units) for treatment, storage, or disposal.	Wastes generated during DNAPL remedy implementation would be required to meet these standards.	X			RAs 3-6A
	27 CCR §20220(b), (c), (d)	All non-hazardous waste, except for liquids, may be discharged to a landfill authorized to accept such waste.	Wastes generated during DNAPL remedy implementation would be required to meet these standards.	X			RAs 3-6A
California Hazardous Waste Control Act (HWCA)	California Health and Safety Code §25100, et seq.	HWCA has many elements that control hazardous wastes from their point of generation through handling, treatment, and ultimate destruction or disposal.	Wastes generated during DNAPL remedy implementation would be required to meet these standards.	X			RAs 3-6A
Code of Federal Regulations Requirement for the Underground Injection Control Program	40 CFR §144-148	Underground Injection Control program federal requirements for state programs. Regulations apply to owners or operators of Class I hazardous waste injection wells. Sections 146.61-146.73 set forth criteria and standards applicable to Class I hazardous waste injection wells. Part 148 sets forth hazardous waste injection restrictions.	If a UIC permit is necessary, the remedy will comply with all substantive requirements.		X		RAs 4-6A
California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65)	Health and Safety Code §25249.5 et seq. 22 CCR §12000	Regulates discharges and exposure of chemicals known to California to be carcinogenic or reproductive toxins.	Notice provisions will be applicable to all candidate DNAPL remedial alternatives (i.e., DDT, BHC, chlordane, PCBs, and benzene).	X			RAs 1-6A

Table 3-1
DNAPL ARARs and TBCs
Montrose Superfund Site

Authority	Citation	Synopsis of Requirement	Action to be Taken to Attain Requirement	Applicable	Relevant and Appropriate	TBC	Remedial Alternative
Clean Air Act of 1963 (CAA)	42 USC §7401-7462, 40 CFR §60-69	Establishes National Emissions Standards for Hazardous Air Pollutants (NESHAPs) for those industrial hazardous air pollutants for which no ambient air quality standards exists, but which cause, or contribute to, air pollution that may result in an increase in mortality or an increase in serious irreversible or incapacitating reversible illness. NESHAP standards are currently limited to very few chemicals for specific sources of those contaminants. The standard for benzene, the only chemical found at the Montrose site for which a NESHAP standard exists, varies depending upon the industrial process. Benzene waste operations, including manufacturing processes are regulated in 61.340-61.358. Chloroform, methylene chloride and toluene are also discussed under NESHAPs; however, no specific emission standards are described (40 CFR 61.01; 50 Federal Register (FR) 39626 and 32628 are the notices announcing that chloroform and that chlorinated benzenes are potentially toxic air pollutants and EPA intends to establish emission standards for the compounds).	Since benzene is not anticipated to be present at levels regulated under NESHAPs, those standards are not applicable. Nor are NESHAPs relevant and appropriate for the remedial activities anticipated since the "fugitive leaks" regulations apply to equipment contacting benzene at concentrations greater than 10% by weight. If benzene is processed during DNAPL remedial alternatives at concentrations meeting the minimum requirements, or if NESHAP standards for chloroform or other site-related toxic air contaminants are promulgated, then the remedial system would be required to comply with these provisions.	X			RAs 4-6A
South Coast Air Quality Management District (South Coast AQMD) Regulation II	Rule 201 and 201.1	Requires that any person building, erecting, installing, altering or replacing any equipment which may cause the discharge of air contaminants obtain a permit and construct/operate the equipment in accordance with the permit conditions.	DNAPL remedial alternatives must have vapor control and treatment systems, designed to comply with the substantive portions of South Coast Air Quality Management District requirements.	X			RAs 3-6A
South Coast AQMD Regulation IV	Rule 401	Limits the discharge of visible emissions.	Vapor control and treatment systems associated with DNAPL remedial alternatives must be designed and operated to comply with these regulations to the extent applicable.	X			RAs 3-6A
	Rule 402	Prohibits discharge of pollutants that (i) cause injury, detriment, nuisance, or annoyance, (ii) endanger the health or safety of the public, or (iii) cause (or tend to cause) injury or damage to business or property.	Vapor control and treatment systems associated with DNAPL remedial alternatives must be designed and operated to comply with these regulations to the extent applicable.	X			RAs 3-6A
	Rule 403	Requires actions to prevent, reduce, or mitigate fugitive dust.	DNAPL remedial alternatives that involve soil handling during remedy construction will need to comply with these requirements. Fugitive dust would need to be controlled using water spray or other common methods. Measurement of dust levels would be performed to document compliance with this rule.	X			RAs 3-6A
	Rule 404	Prohibits discharge of particulate matter in excess of certain concentrations.	Vapor control and treatment systems associated with DNAPL remedial alternatives must be designed and operated to comply with these regulations to the extent applicable.	X			RAs 3-6A
	Rule 405	Prohibits discharge of solid particulate matter in excess of certain rates.	Vapor control and treatment systems associated with DNAPL remedial alternatives must be designed and operated to comply with these regulations to the extent applicable.	X			RAs 3-6A
	Rule 408	Can not build, install or use any equipment that reduces or conceals an emission that would otherwise be a violation.	Vapor control and treatment systems associated with DNAPL remedial alternatives must be designed and operated to comply with these regulations to the extent applicable.	X			RAs 3-6A

Table 3-1
DNAPL ARARs and TBCs
Montrose Superfund Site

Authority	Citation	Synopsis of Requirement	Action to be Taken to Attain Requirement	Applicable	Relevant and Appropriate	TBC	Remedial Alternative
	Rule 409	Limits the emission of particulate matter from a combustion source to 0.10 grain per standard cubic foot, at 12% carbon dioxide, averaged over 15 minutes.	Vapor control and treatment systems associated with DNAPL remedial alternatives must be designed and operated to comply with these regulations to the extent applicable. This rule is potentially applicable to natural gas fired steam boilers or thermal oxidizers.	X			RAs 3-6A
	Rule 466	Any pump, compressor, valve, etc exposed to reactive organic compounds must be equipped with adequate seals and in good working order, except for equipment that is exempted from the requirements for reasons listed in the rule, including equipment in contact with liquid with greater than 80% water content.	Vapor control and treatment systems associated with DNAPL remedial alternatives must be designed and operated to comply with these regulations to the extent applicable.	X			RAs 3-6A
	Rule 474	Limits the concentration of oxides of nitrogen to a range of 125 to 300 ppm for gaseous fuels and 225-400 ppm for solid and liquid fuels depending on equipment size.	Vapor control and treatment systems associated with DNAPL remedial alternatives must be designed and operated to comply with these regulations to the extent applicable. This rule includes provisions for steam generating equipment, which would be applicable to DNAPL remedial alternatives using steam boilers. This rule would additionally apply to natural gas-fired thermal oxidizers for treatment of vapor-phase contaminants.	X			RAs 3-6A
	Rule 476	Steam generating equipment: Prohibits discharge into the atmosphere of certain combustion contaminants from equipment having a heat input rate of more than 50 million BTUs.	DNAPL remedial alternatives involving steam generating equipment would need to comply with this rule if rated at more than 50 million BTUs.	X			RAs 5A and 6A
South Coast AQMD Regulation X	Rule 1001	Regulation of toxic air contaminants. Implements national emissions standards for hazardous air pollutants (NESHAPs) at the local level. Applied to specific process units that discharge specific air toxics.	DNAPL remedial alternatives with process units subject to NESHAP standards, if any, would need to comply with this rule.	X			RAs 3-6A
South Coast AQMD Regulation XI	Rule 1146	Prohibits discharge of certain limits of nitrogen dioxide from steam generators and process heaters rated greater than 5 million BTUs per hour (or between 2-5 million for small operators).	Vapor control and treatment systems associated with DNAPL remedial alternatives (e.g., steam generators used for thermal remediation alternatives) must be designed and operated to comply with these regulations to the extent applicable.	X			RAs 3-6A
	Rule 1166	Regulates volatile organic compound (VOC) emissions from decontamination of soil. This rule establishes requirements for excavation, grading, or handling of soil containing VOCs (i.e., to prevent uncontrolled evaporation of VOCs to the atmosphere). This rule includes requirements for monitoring, odor control, stockpiling, segregation, loading, and transporting VOC-impacted soils. Handling of less than one cubic yard of VOC-impacted soil is exempt from this rule.	DNAPL remedial alternatives that generate more than one cubic yard of VOC-impacted soils (e.g., chlorobenzene) will be subject to this rule. Soil cuttings generated during remedy construction (i.e., well installation) would be subject to this rule and must be handled in a manner consistent with the provisions of this rule to minimize evaporation of VOCs to atmosphere during soil handling.	X			RAs 3-6A
	Rule 1176	Regulates volatile organic compound leaks and emissions from facilities.	Vapor control and treatment systems associated with DNAPL remedial alternatives must be designed and operated to comply with these regulations to the extent applicable.	X			RAs 3-6A
South Coast AQMD Regulation XIII	Rule 1301	Sets forth pre-construction review requirements for new, modified, or relocated sources/facilities, to ensure that the operation of such facilities does not interfere with progress in attainment of the national ambient air quality standards.	Vapor control and treatment systems associated with DNAPL remedial alternatives must be designed and operated to comply with these regulations to the extent applicable.	X			RAs 3-6A

Table 3-1
DNAPL ARARs and TBCs
Montrose Superfund Site

Authority	Citation	Synopsis of Requirement	Action to be Taken to Attain Requirement	Applicable	Relevant and Appropriate	TBC	Remedial Alternative
South Coast AQMD Regulation XIV	Rule 1401	New source review of toxic air contaminants. This rule specifies limits for maximum individual cancer risk (MICR), cancer burden, non-cancer acute, and chronic hazard index. This rule limits emissions of toxic air contaminants to: (a) an MICR less than $1x10^{-6}$ for systems without best available control technology (BACT); (b) an MICR less than $1x10^{-5}$ for systems with BACT; (c) a cancer burden less than 0.5; (d) a chronic hazard index less than 1.0; (e) a non-cancer acute hazard index less than 1.0.	This rule establishes the primary air emission limits for site-related toxic air contaminants including chlorobenzene and chloroform. Chloroform contributes to the MICR and cancer burden. Chlorobenzene is not a carcinogen and only contributes to the hazard index. Vapor control and treatment systems associated with DNAPL remedial alternatives must be designed and operated to comply with this rule.	X			RAs 3-6A
Land Use Covenant Regulation	22 CCR §67391.1 (a), (d)	Establishes substantive requirements for land use restrictive covenants. If hazardous materials, hazardous wastes, or constituents, or hazardous substances will remain at the property after implementation of the remedy at levels which are not suitable for unrestricted use of the land, this requirement would be relevant and appropriate.	A response action decision document which includes limitations on land use or other institutional controls, requires that the limitations or controls are clearly set forth and defined in the response action decision document, specifies that the limitation or controls will be incorporated into a an appropriate land use covenant as required by Section 67391.1, and includes an implementation and enforcement plan. All DNAPL remedial alternatives will be subject to these standards.		X		RAs 1-6A
Environmental Covenant Requirements	CA Civil Code §1471	Specifies manner by which environmental covenants are recorded and binding on successors to the land restricted by the covenant.	If hazardous materials, hazardous wastes or constituents, or hazardous substances will remain at the property after implementation of the remedy at levels which are not suitable for unrestricted use of the land, this requirement would be relevant and appropriate. All DNAPL remedial alternatives will be subject to these standards.		X		RAs 1-6A
City and Municipal codes for electrical, plumbing, and construction	City of Los Angeles Building and Safety Department, 2008 Codes	Provides construction requirements for plumbing, electrical, building, and mechanical code.	DNAPL remedial alternatives involving construction activities of electrical, natural gas, water, or structures would be subject to the substantive portions of these municipal requirements.		X		RAs 3-6A
TO BE CONSIDERED (TBCs)							
Clean Air Act (CAA), National Ambient Air Quality Standards	40 CFR §50.4-50.13	40 CFR §50 establishes primary and secondary National Ambient Air Quality Standards (NAAQS) for ambient air quality to protect public health and welfare, including air pollutant standards for sulfur dioxide, carbon monoxide, nitrogen dioxide, particulate matter, ozone, and lead.	Remediation of DNAPL that would produce a vapor discharge would need to meet NAAQS. Under the CAA, CERCLA sites are considered a "major source" if they emit or have the potential to emit 10 tons per year of any hazardous air pollutant or 25 tons per year of any combination of hazardous air pollutants. NAAQSs are not enforceable at the site level. Any DNAPL remedial alternative with emission of these pollutants in excess of the threshold quantities would be subject to these standards. Vapor control systems associated with DNAPL remedial alternatives would be designed and operated to meet NAAQS, if applicable (e.g. thermal remediation technologies).			X	RAs 3-6A
California Ambient Air Quality Standards	17 CCR §70100 et seq.	Sets ambient air quality standards for ozone, respirable particulate matter, fine particulate matter, carbon monoxide, nitrogen dioxide, sulfur dioxide, lead, visibility reducing particles, sulfates, hydrogen sulfide, and vinyl chloride.	California Ambient Air Quality Standards (CAAQS) are not enforceable on a site level. Vapor control systems associated with DNAPL remedial alternatives would be designed and operated to meet CAAQS, if applicable (e.g. thermal remediation technologies).			X	RAs 3-6A

Table 3-1
DNAPL ARARs and TBCs
Montrose Superfund Site

Authority	Citation	Synopsis of Requirement	Action to be Taken to Attain Requirement	Applicable	Relevant and Appropriate	TBC	Remedial Alternative
California Well Standards, Department of Water Resources	Bulletins 74-90 and 74-81	Provides minimum construction and destruction/abandonment criteria and specifications for groundwater monitoring wells, extraction wells, injection wells, and exploratory borings. The standards are meant to be a model of minimum standards and are enforced locally through Los Angeles County, but are not enforced by the State.	Design, construction, and destruction of wells or borings into the saturated zone must comply with the substantive portions of these standards. Hydraulic displacement and thermal remediation technologies would include wells installed within the saturated zone at the Site and would be subject to these standards.			X	RAs 4-6A
California Global Warming Solutions Act of 2006 (AB32)	Heath and Safety Code §38500 et seq.	California is committed to reducing greenhouse gas emissions to 1990 levels by 2020, which is a reduction of approximately 25%. AB32 includes mandatory reporting rules for significant sources, adoption of a greenhouse gas emissions reduction plan, and adoption of greenhouse gas emission reduction regulations.	The amount of greenhouse gas emissions generated by the candidate DNAPL remedial alternatives will be evaluated. Remedial alternatives that emit high amounts of greenhouse gases will not be ranked as highly as other alternatives.			X	RAs 1-6A
EPA Policy on Green Remediation, April 2008	"Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites"	Encourages consideration and implementation of "green" alternatives for remedial activities, with a focus on energy use, air emissions, water requirements and impacts on water resources, land and ecosystem impacts, material consumption and waste generation and long-term stewardship actions (including reduction of greenhouse gases).	Impact on the environment of all candidate DNAPL remedial alternatives will be evaluated, including evaluation of energy use, waste generation, and greenhouse gas emissions. Alternatives that emit higher quantities of greenhouse gases will not be ranked as highly as other alternatives.			X	RAs 1-6A
EPA Region 9, Cleanup-Clean Air Initiative, March 2008	Smart Energy Resources Guide (SERG), EPA/600/R-08/049	The Smart Energy Resources Guide was created for Region 9's Cleanup-Clean Air Initiative (CCA). The CCA seeks to aid the Superfund Program to remediate sites in a manner that minimizes environmental impacts and to set positive examples for the public and other agencies. The SERG provides information on emissions reduction opportunities to help Superfund remedial project managers make economic decisions about reducing greenhouse gas emissions from energy use in remediation activities at Superfund sites.	Evaluate greenhouse gas emissions from energy use for the various candidate DNAPL remedial alternatives. Alternatives that emit higher quantities of greenhouse gases will not be ranked as highly as other alternatives.			X	RAs 1-6A

Section 4.0

Identification and Screening of DNAPL Remedial Technologies and Process Options

4.0 IDENTIFICATION AND SCREENING OF DNAPL REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

The purpose of this section of the DNAPL FS is to initially screen a list of potentially applicable remedial technologies and process options for each GRA identified in Section 3.2. The remedial technologies and process options are initially screened against three performance criteria including effectiveness, implementability, and relative cost. Remedial technologies and process options retained following this initial screening are then assembled into remedial alternatives as described in Section 5.0.

Several broad technology types may be identified for each GRA, and numerous technology process options may exist within each technology type. The term "technology process options" refers to specific processes within each technology type. For example, ex-situ treatment of soil vapors is a technology type that includes such process options as disposable carbon adsorption, steam-regenerable carbon adsorption, and thermal oxidation. A list of remedial technologies and process options considered for each GRA is provided below:

Candidate Remedial Technologies and Process Options

General Response Action	Remedial Technology/Process Option
No Action	None
Institutional Controls	Deed Restrictions
	Access Restrictions
	Limit Groundwater Use
	DNAPL and Groundwater Monitoring
Containment	Hydraulic Extraction
Extraction Technologies	Soil Vapor Extraction (unsaturated zone)
	Passive DNAPL Extraction
	Hydraulic Displacement (with water injection)
	Surfactant Injection
	Cosolvent Injection
	Polymer Flooding
	Alcohol Flooding
In-Situ Destructive Technologies	In-Situ Bioremediation
	In-Situ Chemical Oxidation
In-Situ Thermal Technologies	Electrical Resistance Heating
	Conductive Heating
	Steam Injection
Ex-Situ Groundwater Treatment	Liquid-Phase Granular Activated Carbon (for MCB) and Advanced Oxidation (for pCBSA)
Ex-Situ Vapor Treatment	Thermal Oxidation with Acid Gas Scrubbing
	Regenerable Carbon/Resin Adsorption
	Disposable Carbon/Resin Adsorption
Disposal	Injection of Treated Water as part of Groundwater Remedy
	Injection of Treated Water as part of Hydraulic Displacement
	Injection of Untreated Water as part of Hydraulic Displacement
	Off-Site Incineration of DNAPL

The remedial technologies and process options are initially screened based on three performance criteria prescribed in the Guidance for Conducting Remedial Investigations and Feasibility Studies under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (EPA, 1988) and summarized as follows:

Effectiveness. Each specific technology is evaluated based on its relative effectiveness in meeting RAOs and protecting human health and the environment. Remedial technologies and process options are evaluated and ranked as effective, moderately effective, minimally effective, potentially effective, or ineffective. This evaluation includes:

- The effectiveness of the remedial technology or process option in achieving the RAOs,
- The potential impacts to human health and the environment during the construction and implementation phase, and
- The reliability of the remedial technology or process option with respect to the contaminants and conditions at the Site.

Implementability. Each remedial technology is evaluated based on the technical and administrative feasibility of implementing the specific technology. Technical feasibility refers to the applicability or compatibility of a remedial process option to site conditions and contaminants of concern. Administrative feasibility refers to such issues as permitting and availability of equipment, among other factors. Each technology is evaluated and ranked as implementable, difficult to implement, or not implementable.

Cost. A limited cost evaluation is performed in this screening phase and is based primarily on engineering judgment and technology vendor experience. Capital costs, such as construction costs, and long-term monitoring or operation and maintenance costs are considered. Each option is evaluated and ranked as very high, high, medium, low, or no cost.

Retention. Following preliminary screening against the above-referenced three performance criteria, a determination is made whether to retain the process options for assembly into remedial alternatives. Process options which are potentially effective and implementable are retained for further consideration. Process options which are not likely to be effective or implementable are eliminated from further consideration. Relative cost is considered in the determination but is not, by itself, a criterion for eliminating a process option from further evaluation.

As described in Section 2.0, DNAPL occurs at the Site in both the unsaturated zone and saturated UBA. Remedial technologies and process options may be applicable to one or both of the DNAPL-impacted zones. Where application of a remedial technology is fundamentally unique to a particular zone, preliminary screening of the technology is conducted separately for that zone. Where a remedial technology is applicable to both zones and not unique to either, preliminary screening is conducted simultaneously for both zones. Preliminary screening of the DNAPL remedial technologies and process options against the three performance criteria is presented in **Table 4.1** and discussed in the following sections.

4.1 NO ACTION

The "No Action" GRA is included in accordance with CERCLA and the NCP. This GRA involves no further action at the Site other than those actions implemented as part of the soil and/or groundwater remedies. The No Action GRA is evaluated simultaneously for both the unsaturated and saturated zones.

Process Description. No further action would be taken at the Site regarding DNAPL other than actions conducted as part of the soil and groundwater remedies. Currently, the Site is covered with a temporary asphalt cap to reduce exposure to shallow unsaturated soils and soil gas containing contaminants of concern. The temporary asphalt cap also reduces the infiltration of rainwater and the rate of contaminant leaching into groundwater from the unsaturated zone. A soil remedy has not yet been selected for the Site but is expected to effectively protect human health and the environment from exposure to shallow contaminated soils and soil gas. Groundwater within the TI Waiver Zone and DNAPL-impacted zones will be hydraulically contained and monitored in the long-term during remedy implementation, as described in Sections 4.3 and 4.2.4 respectfully. Groundwater use within the TI Waiver Zone will also be restricted as described in Section 4.2.3.

Effectiveness. In combination with the remedies for soil and groundwater, the No Action GRA would meet some DNAPL RAOs and be moderately effective in protecting human health and the environment. The remedies for soil and groundwater will effectively prevent human exposure to DNAPL. The containment aspects of the groundwater remedy, as described and separately evaluated in Section 4.3, would slowly reduce DNAPL mass over time by dissolution. Dissolved-phase MCB would be hydraulically contained in the long-term, and the effectiveness of the containment system would be monitored over time. The No Action GRA is by definition a reliable process with no adverse impacts. However, under the No Action GRA, VOC migration in soil gas would not be controlled in the unsaturated zone. ***Rank: Moderately Effective.***

Implementability. By definition, the No Action GRA is highly implementable. ***Rank: Implementable.***

Cost. By definition, there is no cost associated with the No Action GRA. ***Rank: No Cost.***

Retain for Assembly of Remedial Alternatives? As required by the NCP, the No Action GRA will be retained for further evaluation as the baseline for comparison with other remedial technologies and process options. ***Retained? Yes.***

4.2 INSTITUTIONAL CONTROLS

Institutional controls include process options for reducing or eliminating potential exposure to the contaminated media, and they maintain compatible Site use. The applicable process options for institutional controls include deed restrictions, access restrictions, limitations on groundwater use, and groundwater monitoring. Each of these process options are evaluated in the following sections.

4.2.1 DEED RESTRICTIONS

Process Description. Legal restrictions can be added to a Deed of Trust that would limit future use of the Site (e.g. industrial use only). These limitations would address any Site use that may impair protection of human health and the environment such as excavation, drilling, or construction activities. A soil remedy has not yet been selected for the Site, but it is anticipated that deed restrictions will be put in place as part of the soil remedy to protect human health and the environment from exposure to shallow contaminated soil and soil gas.

Effectiveness. Deed restrictions would be effective in limiting future use of the Property and reducing the potential for human exposure to contaminated media. This institutional controls process option meets some of the DNAPL RAOs, and when combined with other GRA process options, would be effective in protecting human health. There are no adverse impacts to human health or the environment associated with the implementation of this process option. This process option is reliable, particularly because much of the area that requires a deed restriction is within the Montrose Property and under the control of Montrose. Although no DNAPL would be directly removed or remediated under a deed restriction, DNAPL mass will be slowly reduced in the long-term by dissolution and the hydraulic containment aspect of the groundwater remedy as specified in Section 4.3. ***Rank: Moderately Effective.***

Implementability. There are no technical or administrative aspects that would limit the implementability of recording a deed restriction for the on-Property portion of the Site, where nearly all of the DNAPL occurs in the subsurface. However, a small portion of the DNAPL may be present below the adjacent property to the north (former Boeing Realty Corporation), and application of deed restrictions at the off-Property areas would require consent of the land owners. ***Rank: Implementable.***

Cost. The relative cost for this alternative is low. ***Rank: Low.***

Retain for Assembly of Remedial Alternatives? Deed restrictions will be retained as a process option for limiting actions which may create exposure to contaminated media. Since some residual DNAPL mass is likely to be left in place following any remedy that may be implemented, this process option is expected to be a required component of the selected remedial alternative. In addition, this institutional controls process option very likely will be a required component of a soil remedy. ***Retained? Yes.***

4.2.2 ACCESS RESTRICTIONS

Process Description. Site access can be limited using physical means such as fences, walls, guards, or security systems. Currently, Site access is restricted by a perimeter chain-link and wrought iron fence, and "No Trespassing" signs are posted along the fenced perimeter. A soil remedy has not yet been selected for the Site, but it is anticipated that access restrictions will be put in place as part of the soil remedy to protect human health and the environment from exposure to shallow contaminated soil and soil gas.

Effectiveness. Access limitations can be effective in reducing the potential for human exposure to Site contaminants. This institutional controls process option meets some of the DNAPL RAOs, and when combined with other GRA process options, would be effective in protecting human health. There are no adverse impacts to human health or the environment associated with the implementation of this process option. This process option is reliable, particularly because much of the area that requires access restriction is within the Montrose Property and under the control of Montrose. Although no DNAPL would be directly removed or remediated under this process option, DNAPL mass will be slowly reduced in the long-term by dissolution and the hydraulic containment aspect of the groundwater remedy as specified in Section 4.3. ***Rank: Moderately Effective.***

Implementability. There are no technical or administrative aspects that would limit the implementability of this process option. This process option does not require any special equipment or personnel. ***Rank: Implementable.***

Cost. The relative cost for this alternative is low. ***Rank: Low.***

Retain for Assembly of Remedial Alternatives? Access limitations are retained as a process option for reducing the potential for human exposure to contaminated media, particularly when combined with other response actions, such as deed restrictions. Since some residual DNAPL mass is likely to be left in place regardless which remedy is implemented, this process option is expected to be a required component of the selected remedial alternative. In addition, this institutional controls process option will very likely be a required component of a soil remedy. ***Retained? Yes.***

4.2.3 LIMIT GROUNDWATER USE

Process Description. Limitations on groundwater use can reduce potential exposure to contaminants and aid in maintaining the integrity of remedial activities. There are several means of restricting use at the Site, including the authority of the Watermaster. Limitations on groundwater use may range from providing notice to future owners of the affected property of the nature and extent of the environmental impacts at the Site, to restricting the use of groundwater. Groundwater use restrictions may limit the ways in which groundwater may be used, or may completely prohibit extraction of groundwater. Legal restrictions can be added to a Deed of Trust that would limit groundwater use. This institutional controls process option is a required component of the groundwater remedy.

Effectiveness. Limiting groundwater use would be effective in eliminating potential exposure routes to DNAPL. Effective means of restricting site use include zoning or land use controls and limitations on groundwater use. Zoning controls are put in place under the authority of the City of Los Angeles or the State of California. This institutional controls process option meets some of the DNAPL RAOs, and when combined with other GRA process options, would be effective in protecting human health. There are no adverse impacts to human health or the environment associated with the implementation of this process option. Although no DNAPL would be directly removed or remediated under a deed restriction or by limiting groundwater use, DNAPL mass will be slowly reduced in the long-term by dissolution and the hydraulic containment aspect of the groundwater remedy as specified in Section 4.3. ***Rank: Moderately Effective.***

Implementability. Limitations on groundwater use may be implemented such that future activity at the Property is compatible with the presence of impacted groundwater. In this case, the restrictions could preclude residential use of the property, prohibit installation of groundwater wells for potable or non-potable use, and generally restrict uses not otherwise required by the groundwater remedy. It is anticipated that the community and the City will desire Site use options which are compatible with surrounding land uses, whenever possible, providing they are consistent with maintaining the integrity of the remedial actions. ***Rank: Implementable.***

Cost. The cost for this process option is low. ***Rank: Low.***

Retain for Assembly of Remedial Alternatives? This process option is retained because of its effectiveness in reducing the potential for human exposure to contaminated groundwater, particularly when combined with other response actions. This institutional controls process option is a required component of the groundwater remedy. ***Retained? Yes.***

4.2.4 DNAPL AND GROUNDWATER MONITORING

Process Description. Monitoring can be performed to determine if DNAPL is migrating laterally or vertically within the subsurface. The sudden appearance of DNAPL in wells that have not contained DNAPL for a significant period of time following installation would be an indication of DNAPL pool migration. Changes in the concentration of dissolved DNAPL constituents in groundwater can be monitored to indirectly assess DNAPL migration. This process option would potentially require installation of wells dedicated for the purpose of monitoring DNAPL. Groundwater monitoring is a required component of the groundwater remedy.

Effectiveness. Monitoring of DNAPL and groundwater can be effective in assessing possible migration of DNAPL or dissolved constituents to other hydrologic units. This institutional controls process option meets some of the DNAPL RAOs, and when combined with other GRA process options, would be effective in protecting human health. There are no adverse impacts to human health and the environment associated with the implementation of this process option. Although no DNAPL would be directly removed or remediated under this process option, DNAPL mass will be slowly reduced in the long-term by dissolution and the hydraulic containment aspect of the groundwater remedy as specified in Section 4.3. ***Rank: Moderately Effective.***

Implementability. There are no technical or administrative aspects that would limit the implementability of this process option. ***Rank: Implementable.***

Cost. The relative cost for this process is low. ***Rank: Low.***

Retain for Assembly of Remedial Alternatives? This process option is retained because of its effectiveness in assessing possible migration of DNAPL or aqueous phase plumes derived from DNAPL dissolution, particularly when combined with other response actions. This institutional controls process option is a required component of the groundwater remedy. ***Retained? Yes.***

4.3 CONTAINMENT

Process Description. Hydraulic containment is a process option for limiting migration of dissolved contaminants in groundwater and reducing the potential for human exposure to contaminated groundwater outside of the containment zone. This process option is a component of the remedy selected for groundwater, and therefore, is automatically retained for assembly into remedial alternatives. Hydraulic containment within the TI Waiver Zone is required for the saturated UBA, underlying BFS, and Gage Aquifer, and is accomplished through groundwater extraction and hydraulic gradient control. Extraction wells located downgradient of the source area are operated to recover contaminated groundwater and prevent contaminant migration outside of the containment zone (or TI Waiver Zone). Although the remedial design of the long-term containment system has not yet been finalized, the following seven extraction wells will be located as described in the EPA Model Development Report (EPA, 2008c) and as shown in **Figure 4.1**:

- UBA Extraction Wells: UBA-EW-A, UBA-EW-B, and MBFB-EW-1
- BFS Extraction Wells: BF-EW-1, BF-EW-M, and BF-EW-N
- Gage Extraction Well: G-EW-1

A total of approximately 200 to 250 gpm would be extracted from a combination of these wells to contain dissolved-phase contaminant migration (primarily MCB). Groundwater would be treated ex-situ at the Property and then re-injected into the Gage through the following two injection wells at the completion of the groundwater restoration:

- Gage Injection Wells: G-IW-2 and G-IW-D

Dissolved contaminants within the DNAPL-impacted UBA would be extracted and hydraulically contained from migrating downgradient. The lateral hydraulic gradient would be controlled to ensure containment of the dissolved-phase MCB plumes, and the vertical hydraulic gradient would be controlled to minimize the potential for downward migration of DNAPL or dissolved-phase MCB. This process option is a required element of the groundwater remedy.

Effectiveness. Hydraulic containment is an effective method for preventing migration of dissolved-phase constituents and reducing the potential for human exposure to contaminated groundwater. This process option meets the DNAPL RAOs since DNAPL mass is slowly reduced through dissolution. The MCB component of the DNAPL will slowly solubilize into groundwater as it flows through the DNAPL-impacted UBA. Dissolved-phase MCB will then be extracted by the downgradient containment wells for ex-situ treatment, thereby gradually reducing DNAPL mass over time. In the absence of a more aggressive DNAPL source removal remedy, the duration of hydraulic containment at the Site required to reach residual DNAPL levels in the UBA such that it would cease to impact groundwater in concentrations exceeding the in-situ groundwater standard of 70 ug/L MCB (as specified in the ROD; EPA, 1999) was estimated by H+A at approximately 4,900 years (H+A, 2009c).

Containment is one of the most frequently implemented process options at DNAPL-impacted sites. In a December 2003 EPA study (EPA, 2003), an expert panel acknowledged the use of containment at DNAPL sites as follows:

> "*…for the vast majority of groundwater-contaminated sites where DNAPL is suspected or known to be present, site remediation strategies are dominated by containment technologies, coupled with long-term monitoring. This strategy has been effective at limiting the spread of contaminants at these sites and significantly reducing the risk of human and ecological exposures to these chemicals…*"

The expert panel from the 2003 EPA study established a decision process for evaluating the potential applicability of source zone depletion at a site. The panel established three different categories for source zone depletion criteria, which are compared against Montrose Site conditions below:

1. Factors when source depletion is needed. None of these factors match Montrose Site conditions.
2. Factors when source depletion may or may not be considered. Two of the factors match Montrose Site conditions including:
   - Free-phase DNAPL present in stable stratigraphic traps
   - Stable dissolved-phase plume
3. Factors when source depletion is less needed. Six of the factors match Montrose Site conditions including:
   - Containment costs are significantly less than the cost of source depletion (see Section 7.7 for cost comparison)
   - High reliability of containment system, which has been demonstrated by EPA with the groundwater modeling at the site

- Low resource value (i.e. low yield hydrogeologic unit) , which is true for the UBA
- Low probability of a meaningful reduction in time to reach MCLs, which has estimated to be on the order of 3,000 to 5,000 years
- No users of resource within expected time frame
- Desire to not expend financial resources for limited risk reduction benefits.

Based on the decision process proposed by the EPA-sponsored expert panel, containment of the DNAPL source is more applicable to the Montrose Site than active source depletion. Containment is additionally a highly reliable process option for protecting human health and the environment. Unlike some of the more aggressive source zone remediation technologies, such as steam injection, there are no significant adverse impacts associated with containment that could result in the spreading of contamination. The 2003 expert panel recognized potential adverse affects of source depletion. Specifically, the panel recognized the potential for thermal remediation to:

- Expand the source zone if trapped DNAPL is mobilized;
- Form mineral deposits as low permeability layers (depending on the geochemistry);
- Change the composition and behavior of DNAPLs, making them more mobile or more toxic; and
- Result in selective removal of the more volatile constituents, leaving behind higher molecular weight components as residuals, which would be the case at the Montrose site in which DDT which is a more toxic substance would not be removed in the most part by the implementation of a DNAPL thermal remedy.

Further, the 2003 EPA study also recognized the potential limitations associated with DNAPL source depletion technologies currently available today and indicated:

> "*…there is a lack of consensus regarding the appropriateness of applying intensive and often costly remediation technologies for DNAPL extraction or destruction in the source zone, if such partial mass removal will not have a quantifiable and substantial impact on the duration and life-cycle costs of a containment remedy, such as pump-and-treat*"

The 2003 EPA study noted that achieving drinking water standards was beyond the ability of available source zone depletion technologies and was unlikely to occur within a reasonable time frame at the vast majority of DNAPL sites.

> "*Although source depletion technologies are capable of removing substantial amounts of the DNAPL in source zones at sites with favorable hydrogeologic conditions (i.e., less heterogeneous and more permeable subsurface conditions), achievement of drinking water MCLs in these source*

zones as well as source zones in more challenging heterogeneous hydrogeologic conditions (e.g., bedrock, karst systems, multiple stratigraphic units) is unlikely."

Despite technological advances, effective remediation of DNAPL-impacted source zones remains problematic, and many technical experts question the cost-benefit of aggressive source zone remediation technologies. In a 2000 paper (Freeze, 2000), the author advocated implementation of source containment due to the technical impracticability of removing sufficient DNAPL mass to reduce contaminant concentrations to cleanup standards. In a separate evaluation in 2006 (McGuire, et. al., 2006), the authors recognized that the uncertainties and relatively high costs of many source depletion technologies discouraged their use.

> "*The degree of uncertainty in the costs and benefits of applying source depletion technologies is currently at levels that discourage widespread use of the available source depletion technologies at DNAPL sites*".

H+A also estimated the potential reduction in required containment duration resulting from various DNAPL source zone remedies. Assuming DNAPL mass reductions between 17% and 90%, the required duration of the hydraulic containment system was estimated to be between approximately 3,100 and 4,700 years after implementation of a source zone remedy. However, removal of even 80% to 90% of the DNAPL mass is considered an optimistic, high-end assumption for mass removal at the Site. Although there is some variability in the assumptions used to estimate the containment timeframes, the cost-benefit of applying aggressive source zone remediation must be considered given the exceptionally long duration required for hydraulic containment even after implementation of a DNAPL source zone remedy. Containment is an effective method for protecting human health and the environment both now and in the future, when more technical and cost effective source depletion remedial technologies are developed. ***Rank: Effective.***

Implementability. As a component of the groundwater remedy, hydraulic containment is, by definition, implementable. ***Rank: Implementable.***

Cost. As a required component of the groundwater remedy, there is no incremental cost associated with hydraulic containment. ***Rank: No Cost.***

Retain for Assembly of Remedial Alternatives? As a component of the groundwater remedy, hydraulic containment is automatically retained for assembly into DNAPL remedial alternatives. ***Retained? Yes.***

4.4 EXTRACTION TECHNOLOGIES

Process options associated with this GRA include direct extraction of DNAPL from the subsurface. The majority of the process options evaluated in this section include extraction of DNAPL or DNAPL/groundwater. However, MCB, a volatile component of DNAPL, can additionally be removed as a vapor-phase constituent in soil gas from the unsaturated zone. Extraction technologies evaluated in this section include SVE, passive DNAPL recovery, hydraulic displacement, and four process options for enhanced DNAPL recovery. The four process options for enhanced DNAPL recovery are discussed in Sections 4.4.4 through 4.4.7 and include surfactant injection, cosolvent injection, polymer flooding, and alcohol flooding. These four process options are all mobilization technologies that are very similar in nature, and therefore, the performance evaluation of these process options is also similar. These process options do not involve in-situ destruction or thermal remediation of DNAPL, which are discussed in subsequent sections.

4.4.1 SOIL VAPOR EXTRACTION

Process Description. SVE is a remedial technology for removing VOCs, including MCB, from permeable unsaturated soils. VOCs occurring in the unsaturated zone, sorbed to soil grains or as a component of DNAPL, will partition into soil gas (air-filled pore spaces) according to their physical properties and can be extracted using SVE. Under this process option, a series of extraction wells would be positioned throughout the VOC-impacted unsaturated zone, and a vacuum would be applied to wells to induce soil vapor flow through permeable soil layers. The soil vapors are extracted from the wells using a vacuum blower and treated ex-situ prior to atmospheric discharge.

The basic components of this technology include unsaturated zone extraction wells, vacuum blowers, and a piping network. SVE can be implemented as a stand-alone technology for the unsaturated zone or as a component of saturated zone technologies that convert liquid-phase contaminants to vapor-phase (e.g. thermal technologies). SVE will not remove the non-volatile DDT component of DNAPL and is not applicable to the saturated zone (i.e., water-filled pore spaces). With the exception of DNAPL extraction by hydraulic displacement, all of the remedial process options discussed in this DNAPL FS will result in DDT being left in the subsurface, either in the unsaturated zone or below the water table, once the volatile MCB component is removed.

Effectiveness. SVE is highly effective in reducing DNAPL mass and mobility in permeable unsaturated soils and meets DNAPL RAOs. The effectiveness of SVE is primarily dependent on two factors, contaminant volatility and soil permeability to air. SVE will be effective for removal of volatile contaminants from permeable soils. SVE will be significantly less effective (or ineffective) for removal of contaminants from low permeability soils or for removal of semi-volatile or non-volatile contaminants. The effectiveness of SVE to remove MCB and other VOCs from the unsaturated zone was tested in 2003, as summarized in Section 2.6.4. Based on the pilot test results, SVE was found to be effective for removal of MCB and other VOCs from the PVS (25-45 feet bgs) and unsaturated UBA (45-60 feet bgs). Between 223 and 472 pounds per day of VOCs was removed from one well screened within each of these two unsaturated zone layers, where approximately 261,000 pounds of MCB is estimated to occur (Section 2.2.4). The effective radius of influence observed during the pilot test was 123 feet for the PVS and 64 feet for the unsaturated UBA. However, SVE was found to be significantly less effective for removal of MCB and other VOCs from the low permeability PD (4-25 feet bgs). An elevated vacuum of 18 inches of mercury was required to initiate soil vapor flow in the PD, and subsequently, a significant amount of vertical communication between the PD and underlying PVS was observed. Control of VOC migration in soil gas from the PD to land surface is being addressed as part of the Soil FS report (in press).

Although SVE will not remove the non-volatile DDT component of the DNAPL, the mobility of the DNAPL in the unsaturated zone would be significantly reduced by vaporization of the MCB component. As the MCB component of the DNAPL is vaporized, the DDT component will precipitate, sorb to soil, and become relatively immobile in the environment (DDT tends to sorb strongly to soil). Removal of the MCB component of the DNAPL is an effective method for reducing the mass and mobility of the DNAPL in the subsurface. Implementation of SVE would additionally control and prevent VOC migration in soil gas within the unsaturated zone. SVE will not be effective in treating any DNAPL in the saturated zone (water-filled pore spaces). Additionally, the water table has been slowly rising for several years as indicated in Section 1.5.2, and continued rising of the water table will reduce the thickness of the unsaturated UBA available for application of SVE. ***Rank: Highly Effective (in permeable unsaturated soils).***

Implementability. There are no technical or administrative aspects that would limit the implementability of this remedial technology. A remedial alternative including SVE would have to meet ARARs for air emissions. ***Rank: Implementable.***

Cost. The relative cost for SVE is medium. While the cost of extracting soil vapors is low, the cost to treat the soil vapors ex-situ increases the ranking to medium. Ex-situ soil vapor treatment process options are evaluated in Section 4.8. ***Rank: Medium.***

Retain for Assembly of Remedial Alternatives? SVE is retained because of its effectiveness in extracting MCB and other VOCs from permeable unsaturated soils, specifically the PVS and unsaturated UBA. ***Retain? Yes.***

4.4.2 PASSIVE EXTRACTION OF DNAPL

Process Description. Passive extraction is a process option for removal of mobile DNAPL that accumulates in wells (gravity induced migration) screened within the saturated UBA. As described in Section 2.5.6, mobile DNAPL passively accumulates in a small number of wells located in the CPA and screened in the saturated UBA. Under this remedial technology, a higher density of wells would be installed within the source area to recover mobile DNAPL pooled above low permeability silt layers (capillary barriers). DNAPL would be purged from the well sumps as it passively accumulates and then be disposed off-Site. DNAPL collection would continue as long as DNAPL accumulates in the well sumps. Under this process option, injection and/or withdrawal of water to hydraulically displace the DNAPL is not utilized.

Effectiveness. Passive recovery is effective in recovering mobile DNAPL that intercepts the well screens and meets DNAPL RAOs. As described in Section 2.5.6, a total of 256 gallons of DNAPL has been passively recovered at the Site since 1988, which is less than 1% of the 76,000 gallons of total DNAPL estimated to be present in the saturated UBA (as described in Section 2.5.5). It is also less than 2% of the 21,000 gallons of mobile DNAPL estimated to be present in the saturated UBA (Appendix E). It is noted that a substantial portion of the DNAPL present at the Site may already be at residual concentrations and thus immobile and not affected by this process option. While a significantly higher density of wells than exist now would be implemented under this process option, only a portion of the mobile DNAPL present in the subsurface would be expected to intercept the passive recovery wells. This process option is effective in removing some mobile DNAPL, but the potentially low volumes yielded would have a minimal impact in reducing the mass of DNAPL in the subsurface. ***Rank: Minimally Effective.***

Implementability. Passive DNAPL recovery has been on-going at the Site since 1988 and is implementable. There are no technical or administrative aspects that would limit the implementability of this remedial technology. ***Rank: Implementable.***

Cost. The relative cost of this process option is low. ***Rank: Low.***

Retain for Assembly of Remedial Alternatives? This process option is not retained because, as a source depletion technology, it is minimally effective in recovering mobile DNAPL from the saturated UBA. ***Retained? No.***

4.4.3 HYDRAULIC DISPLACEMENT

Process Description. Under this process option, groundwater is simultaneously extracted and injected to induce hydraulic gradients that mobilize DNAPL towards extraction wells. Unlike passive recovery, this process option actively facilitates DNAPL movement towards the extraction wells for subsequent extraction. Longer DNAPL pools, which contain large amounts of mass, are easier to displace than shorter pools containing small amounts of mass. Implementation of this process option requires installation of extraction wells throughout the DNAPL-impacted zone and simultaneous pumping of groundwater and DNAPL. The DNAPL can be extracted as a commingled mixture with the groundwater or pumped separately if accumulating in the well sumps. Initially, the extracted DNAPL/groundwater requires separation, followed by off-Site disposal of the DNAPL and re-injection of the groundwater. The groundwater can additionally be treated ex-situ to remove dissolved-phase contaminants prior to re-injection, as needed. Process options for groundwater re-injection or disposal are evaluated separately in Section 4.9.

Effectiveness. Hydraulic displacement is highly effective in recovering mobile DNAPL. This process option meets DNAPL RAOs, is effective in reducing DNAPL mass, and is highly effective in reducing DNAPL mobility. DNAPL mobility is a function of saturation, and the highest saturations are the most mobile. Hydraulic displacement is a depletion technology that continuously reduces the DNAPL mobility over time until residual saturations are achieved. Hydraulic displacement has the potential to recover DNAPL occurring in saturations above residual levels. As indicated in Section 2.1.2, a residual DNAPL saturation of 18.9% was measured in one soil core following water displacement at increasing capillary pressures (residual saturation observed at capillary pressure of 1.8 psi). Although residual saturations of DNAPL would be left in place by this process option, residual DNAPL is immobile in the environment and poses little or no risk of mobilization (other than as a continuing source of dissolved-phase MCB to groundwater).

Hydraulic displacement was field pilot tested at the Site in 1991, 2004/2005, and 2008 as described in Section 2.6.2. In 1991, a 28-day DNAPL extraction pilot test was conducted at well UBE-1 (H+A, 1992), and approximately 300 gallons of DNAPL was recovered at an average rate of approximately 10.4 gallons per day. Groundwater was extracted at an average rate of approximately 7.0 gpm. The DNAPL recovery rate observed during this pilot was approximately 100 to 1,000 times faster than recovered at the Site via passive extraction.

A second DNAPL extraction pilot test was conducted from March 2004 through January 2005 at wells UBT-1 and UBE-1 through UBE-4 (H+A, 2007c). Approximately 420 gallons of DNAPL was recovered during the pilot test with DNAPL recovery rates varying from 0.5 to 5.6 gallons per day. Groundwater was extracted at varying rates between 1.9 and 11.8 gpm, and hydraulic displacement was found to be most effective at the higher groundwater extraction rates (i.e. higher hydraulic gradient). Hydraulic displacement was also found to be most effective for wells located at the source areas within the CPA. Particularly, moderate to elevated DNAPL recovery rates were observed at UBE-1, UBT-1, and UBE-4 located at the DNAPL source areas within the CPA. Wells UBE-2 and UBE-3 are located east of the DNAPL source areas and are believed to be located in areas containing only residual DNAPL (i.e., no mobile DNAPL). Hydraulic displacement pilot testing at wells UBE-2 and UBE-3 confirmed that there is minimal or no mobile DNAPL at these two locations.

A third DNAPL extraction pilot test (short-term test) was conducted in December 2008 at well UBE-5, located adjacent to DNAPL reconnaissance boring SSB-12. During the 5-day extraction test, approximately 1.4 gallons of DNAPL was recovered from UBE-5. The drawdown in the extraction well was increased to approximately 24 feet on the last day, and during this short period, DNAPL was recovered at an increased rate equivalent to 5.4 gallons per day (0.23 gallons per hour). The screened interval at UBE-5 is only 10 feet long (from 75 to 85 feet bgs) so that hydraulic displacement could be focused on a specific DNAPL-impacted interval. As a result, groundwater extraction rates during the short-term test were between 1.0 and 1.75 gpm. Hydraulic displacement effectively recovered mobile DNAPL at UBE-5, located southeast of the CPA in an isolated area exhibiting mobile DNAPL saturations.

The DNAPL extraction pilot tests conducted at the Site did not include groundwater re-injection for purposes of enhanced gradient control and DNAPL flushing. Groundwater was re-injected during the 2004/2005 test outside of the DNAPL-impacted area and for disposal purposes only. The effectiveness of hydraulic displacement is expected to increase when groundwater is re-injected to enhance the hydraulic gradient.

Under typical hydraulic gradients, residual DNAPL, by definition, cannot be mobilized by hydraulic displacement and would not be removed by this process option. Although residual DNAPL is already immobile in the environment, the MCB component of the DNAPL will solubilize into groundwater at an accelerated rate as a result of the hydraulic flushing if the extracted groundwater is treated first to remove VOCs prior to re-injection (as compared with the natural hydraulic gradient at the Site). To facilitate such solubilization, dissolved-phase MCB can be treated ex-situ prior to re-injection and is evaluated in Section 4.9.

The saturated UBA is heterogeneous and layered. Discontinuous sand layers which are not in hydraulic communication with the extraction wells may limit the effectiveness of a displacement technology. There is also a small risk of vertical pool mobilization, although the horizontally bedded nature of the deposits is expected to limit such migration. The potential for downward mobilization was evaluated by H+A and Intera by modeling, and model results indicated there was no downward mobilization past the basal silty sand member of the UBA during or after hydraulic displacement assuming conservatively thick DNAPL pool heights up to 8 feet (H+A, 2009b). A higher density of injection and extraction wells can mitigate this risk to a large part by minimizing the potential for a discontinuity to occur between wells. ***Rank: Effective.***

Implementability. This remedial technology is implementable and has been pilot tested at the Site, without groundwater re-injection for enhanced hydraulic gradients. Extraction wells can be installed using standard drilling methods and equipment. Standard separation techniques can be used to separate DNAPL from groundwater. Precipitate fouling of the extraction pump and piping was observed during the extraction pilot test, but such effects can be abated through routine maintenance. If re-injection of untreated groundwater is selected as the disposal process option for the remedy, then administratively, the re-injection limits specified in the groundwater ROD would need to be waived in order to implement the remedy (which was approved for the 2004/2005 extraction test). It should be noted that re-injection would occur within the footprint of the TI waiver zone. ***Rank: Implementable.***

Cost. The relative cost for hydraulic displacement is low to medium, depending on the groundwater treatment process option selected as part of the remedial alternative. If the groundwater is separated from the DNAPL and re-injected untreated, then the relative cost for this remedial technology is low. However, if groundwater treatment is required to meet re-injection limits specified in the groundwater ROD, then the relative cost of this process option increases to medium, due to the elevated concentrations of MCB and pCBSA in UBA groundwater. Groundwater treatment/disposal process options are evaluated in Section 4.9, and ex-situ groundwater treatment technologies are evaluated in Section 4.7. ***Rank: Low to Medium.***

Retain for Assembly of Remedial Alternatives? This process option is retained because of its effectiveness in recovering mobile DNAPL, reducing DNAPL mass and mobility, as demonstrated during field pilot studies. ***Retain? Yes.***

4.4.4 SURFACTANT INJECTION

Process Description. A surfactant is a surface active agent that serves to change fluid wettability and interfacial tension. Injecting surfactant solutions into a DNAPL-impacted zone can both increase the rate of DNAPL dissolution into water (solubilization flood) and increase the rate of DNAPL recovery during hydraulic displacement (mobilization flood). Surfactants chosen to achieve ultra-low interfacial tensions are employed in a mobilization flood. Surfactants chosen to increase DNAPL solubility without achieving ultra-low interfacial tensions are employed in a solubilization flood. Surfactants chosen to facilitate a solubilization flood will lower the DNAPL-water interfacial tension, but not to the same extent as surfactants chosen for a mobilization flood. Likewise, surfactants chosen to facilitate a mobilization flood will increase the rate of DNAPL dissolution into water. Surfactant injection is a process known as surfactant-enhanced aquifer remediation (SEAR). This process option involves injection of a surfactant which is flushed through the source zone, followed by recovery of the injected solution and targeted DNAPL.

Effectiveness. Surfactant injection has not been bench or pilot tested for this Site, and its potential effectiveness is highly uncertain. Surfactant injection has been infrequently applied as a full-scale remedy at DNAPL sites, and its potential effectiveness has not been demonstrated at a site comparable to the Montrose Site. Although DNAPL mass may be reduced by this process option, DNAPL mobility would be increased rather than reduced, which is not in accordance with DNAPL RAOs.

This process option is potentially effective in removing additional DNAPL (both pooled and residual) from the saturated UBA as an enhancement to a hydraulic displacement remedy. Surfactants chosen to facilitate a mobilization flood can significantly reduce the interfacial tension between the water and DNAPL (below 0.1 dynes per centimeter), liberating more DNAPL for recovery by hydraulic displacement. Alternatively, a solubilization flood could be implemented following hydraulic displacement to facilitate further removal of DNAPL through dissolution. However, the greatest limitation to the use of surfactants at the Site is the heterogeneous nature of the UBA. In order for surfactants to be effective at removing DNAPL, they must first come in physical contact with the DNAPL. Injected surfactants may channel along preferential flow paths toward extraction wells, and the majority of benefits of surfactants would only be realized in these areas of preferential flow.

Mobilization risks for DNAPL, either downward or laterally outside the recovery wellfield, are increased under this process option. This technology is more effective at sites underlain by a thick, continuous, and low permeability confining layer. With injected surfactants, the DNAPL mobility must be controlled and the mobilized DNAPL must be recoverable to prevent uncontrolled lateral or vertical spreading of the contamination. Additionally, DNAPL and groundwater/surfactant solutions can be difficult to separate once recovered, resulting in additional aboveground treatment costs. ***Rank: Potentially Effective (but highly uncertain).***

Implementability. This process option is potentially implementable at the Site, although achieving a uniform distribution of the surfactant throughout the heterogeneous UBA will reduce the effectiveness of this process option. Laboratory studies would also be necessary to determine an appropriate surfactant mixture based on the nature of the DNAPL and Site geochemistry. Specialized chemicals and contractors would be required to implement this process option, and regulatory approval of the use of surfactants would be required prior to injection. A tracer test would be required to assess the degree of heterogeneity in the saturated zone prior to implementing this process option. ***Rank: Difficult to Implement.***

Cost. The relative cost for this process option is high. Increased waste disposal costs can be incurred under this process option due to the difficulty in separating DNAPL from a groundwater/surfactant solution. ***Rank: High.***

Retain for Assembly of Remedial Alternatives? This process option is not retained for further evaluation partly because surfactant injection has been infrequently applied as a full-scale remedy at DNAPL sites, and its potential effectiveness has not been demonstrated at a site comparable to the Montrose Site. Although DNAPL mass may be reduced by this process option, DNAPL mobility would be increased rather than reduced, which is not in accordance with DNAPL RAOs. Another limitation is the preferential flow of the surfactants along the coarse-grained portions of the UBA. Additionally, this process option is not retained due to the lack of an effective confining layer overlying the BFS and the increased potential for downward mobilization of DNAPL, as compared with other remedial technologies. The uncertainty associated with the potential effectiveness of this process option is very high. ***Retained? No.***

4.4.5 COSOLVENT INJECTION

Process Description. Cosolvents are typically low-concentration (approximately 1% to 5% by volume) alcohol solutions used to enhance DNAPL dissolution and facilitate mobilization. This process option is an enhancement to hydraulic displacement and involves injection of a cosolvent, flushing it through the source zone, and recovery of the injected solution and DNAPL. Cosolvents are compounds miscible in both water and DNAPL, which may partition preferentially into one or the other depending on the chemical properties and concentration of the cosolvent and DNAPL. Alcohols, ethyl lactate, and ketones are types of compounds used as cosolvents. Cosolvents are similar to surfactants in that they can alter the properties of DNAPLs by increasing the solubility and lowering the interfacial tension. Enhanced dissolution and DNAPL mobilization are the two general removal mechanisms of cosolvents.

Effectiveness. Cosolvent injection has not been bench or pilot tested for this Site, and its potential effectiveness is highly uncertain. Cosolvent injection has been infrequently applied as a full-scale remedy at DNAPL sites, and its potential effectiveness has not been demonstrated at a site comparable to the Montrose Site. Although DNAPL mass may be reduced by this process option, DNAPL mobility would be increased rather than reduced, which is not in accordance with DNAPL RAOs.

This process option is potentially effective in removing additional DNAPL (both pooled and residual) from the saturated UBA as an enhancement to a hydraulic displacement remedy. The density of DNAPL will decrease as the lower density alcohol partitions into the DNAPL, which has the advantage of decreasing the potential for vertical DNAPL mobilization. However, the low density of many alcohols (lighter than water) can pose challenges in delivering cosolvents to all target soil horizons below the water table.

The effectiveness and implementability of using cosolvents at the Site are limited by the same factors that limit the use of surfactants. In order for cosolvents to be effective at removing DNAPL, they must first come in physical contact with the DNAPL. Cosolvents would channel along preferential flow paths towards extraction wells, and the benefits of the cosolvents would be realized in these areas of preferential flow. The DNAPL mobility must be controlled and the mobilized DNAPL must be recoverable to prevent uncontrolled lateral or vertical spreading of the contamination. Large volumes of water, DNAPL, and cosolvent waste are generated that must be separated and treated at the surface. It can be difficult to remove the DNAPL from extracted groundwater when cosolvents are present.

An unknown with this technology is the potential for in-situ precipitation of the DDT. DDT is less soluble in some alcohols than in MCB. As the cosolvent partitions into the DNAPL, a portion of the DDT may precipitate. This phenomenon was previously demonstrated at the Site by adding methanol to the Montrose DNAPL. Significant in-situ precipitation of the DDT may result in plugging of the soil pores, reducing the effective permeability of the formation. ***Rank: Potentially Effective (but highly uncertain).***

Implementability. This process option is potentially implementable at the Site, although uniform distribution of the cosolvent throughout the heterogeneous UBA may be problematic. Laboratory studies would be necessary to determine the correct cosolvent based on the nature of the DNAPL and site geochemistry. Specialized chemicals and contractors would be required to implement this process option, and regulatory approval of the use of cosolvents would be required prior to injection. A tracer test would be required to assess the degree of heterogeneity in the saturated zone prior to implementing this process option. ***Rank: Difficult to Implement.***

Cost. The relative cost of this process option is high. Increased waste disposal costs can be incurred under this process option due to the difficulty in separating groundwater from a DNAPL/co-solvent solution. ***Rank: High.***

Retain for Assembly of Remedial Alternatives? This process option is not retained for further evaluation partly because cosolvent injection has been infrequently applied as a full-scale remedy at DNAPL sites, and its potential effectiveness has not been demonstrated at a site comparable to the Montrose Site. Although DNAPL mass may be reduced by this process option, DNAPL mobility would be increased rather than reduced, which is not in accordance with DNAPL RAOs. Another limitation is the preferential flow of the cosolvents along the coarse-grained portions of the UBA. Additionally, this process option is not retained due to the lack of an effective confining layer overlying the BFS and the potential for in-situ precipitation of the DDT and plugging of the formation. The uncertainty associated with the potential effectiveness of this process option is very high. ***Retained? No.***

4.4.6 POLYMER FLOODING

Process Description. Injecting polymers into a DNAPL-impacted zone may enhance the extraction rate of DNAPL from the subsurface by increasing the viscosity of the displacing fluid (groundwater). Polymers, such as xanthan gum, are added to groundwater and re-injected to improve the mobility ratio of the DNAPL-water system by increasing the aqueous solution viscosity to above that of the DNAPL. Viscosities in the range of 5 to 20 centipoises are common for polymer solutions. Polymers have been used to reduce the fingering of the displacing fluid (water) past the displaced fluid (DNAPL) and to help ensure that the contaminated area is more efficiently swept. Polymers can be used to increase the sweep efficiency (degree of contact with the DNAPL) during a surfactant flood, a cosolvent flood, an alcohol flood, and during hydraulic displacement. As a stand-alone technology, polymer flooding can only displace mobile DNAPL.

Effectiveness. Polymer flooding has not been bench or pilot tested for the Site, and its potential effectiveness is highly uncertain. Polymer flooding has been infrequently applied as a full-scale remedy at DNAPL sites, and its potential effectiveness has not been demonstrated at a site comparable to the Montrose Site. Although DNAPL mass may be reduced by this process option, DNAPL mobility would be increased rather than reduced, which is not in accordance with DNAPL RAOs.

This process option is potentially effective in removing additional mobile DNAPL from the saturated UBA as an enhancement to a hydraulic displacement remedy. Unlike surfactant and cosolvent injection, polymers can effectively increase the mobility of the DNAPL by increasing the viscosity of the injected groundwater. Although the use of polymers can enhance the efficiency of hydraulic displacement, the technology is still subject to many of the same limitations as other remedial technologies that rely on injection and recovery from the UBA. For contaminant-impacted areas as heterogeneous as the UBA, significant limitations on the effectiveness of polymer injection exist. The polymer would preferentially flow through the portions of the aquitard with the highest conductivities. This means that the majority of benefits from the polymer would be realized in areas of preferential flow, much like other technologies where flushing of the contaminant zone is required. A disadvantage of polymer injection is the increased potential for injection well fouling, further limiting the effectiveness of this process option. ***Rank: Potentially Effective (but highly uncertain).***

Implementability. This process option is potentially implementable at the Site. Specialized chemicals and contractors would be required to implement this process option, and agency approval of the use of polymers would be required prior to injection. The injection of polymers into the subsurface may be problematic. Injection rates are often only 50 percent of the extraction rates due to a variety of factors which may affect the performance of injection wells in the DNAPL-impacted area. A tracer test would be required to assess the degree of heterogeneity in the saturated zone prior to implementing this process option. ***Rank: Difficult to Implement.***

Cost. The relative cost of this process option is high. Increased costs can be incurred due to injection well fouling. ***Rank: High.***

Retain for Assembly of Remedial Alternatives? This process option is not retained for further evaluation partly because polymer flooding has been infrequently applied as a full-scale remedy at DNAPL sites, and its potential effectiveness has not been demonstrated at a site comparable to the Montrose Site. Although DNAPL mass may be reduced by this process option, DNAPL mobility would be increased rather than reduced, which is not in accordance with DNAPL RAOs. Another limitation is the preferential flow of the polymers along the coarse-grained portions of the UBA and the potential for severe plugging of the formation and wells. Additionally, this process option is not retained due to the lack of an effective confining layer overlying the BFS and the increased potential for downward mobilization of DNAPL, as compared with other remedial technologies. The uncertainty associated with the potential effectiveness of this process option is very high. ***Retained? No.***

4.4.7 ALCOHOL FLOODING

Process Description. Alcohol flooding is a process involving the use of very high-concentration alcohol solutions to extract both residual and pooled DNAPL. The distinction between this process option and cosolvent injection is the concentration (cosolvent injection involves dilute forms of alcohols, i.e. 1-5% by volume). The use of alcohol concentrations greater than approximately 70% by volume will eliminate the interfacial tension between DNAPL and water, resulting in a miscible mixture of water, alcohol, and DNAPL components. This miscible mixture can be either less or more dense than water depending on the particular alcohol employed and the associated phase behavior. The use of alcohol concentrations less than those required to achieve miscibility would result in increased DNAPL dissolution into water and a lowering of DNAPL-water interfacial tension, similar to that achieved with surfactants (but due to a different mechanism). Low molecular weight alcohols, such as methanol and ethanol, have principally been used for high concentration alcohol flooding of source zones. Higher molecular weight alcohols, such as propanols, can result in significant DNAPL swelling and reduction of DNAPL density, thereby off-setting the risk of vertical DNAPL mobilization associated with interfacial tension lowering. The application of an upward hydraulic gradient during alcohol flooding also reduces the risk for downward vertical mobilization.

Effectiveness. Alcohol flooding has not been bench or pilot tested at the Site, and its potential effectiveness is highly uncertain. Alcohol flooding has been infrequently applied as a full-scale remedy at DNAPL sites, and its potential effectiveness has not been demonstrated at a site comparable to the Montrose Site. Although DNAPL mass may be reduced by this process option, DNAPL mobility would be increased rather than reduced, which is not in accordance with DNAPL RAOs.

This process option is potentially effective in removing pooled and residual DNAPL from the saturated UBA. The density of the DNAPL will decrease as the lower density alcohol partitions into the DNAPL, which has the advantage of decreasing the potential for downward vertical DNAPL mobilization. However, the low density of many alcohols that are lighter than water can pose challenges in delivering them to all target soil horizons below the water table. The effectiveness of an alcohol flood at the Site is limited by the same factors that limit the use of surfactants and cosolvents. The DNAPL mobility must be controlled and the mobilized DNAPL must be recoverable to prevent uncontrolled lateral or vertical spreading of the contamination. Large volumes of water, DNAPL, and alcohol waste are generated that must be separated and treated at the surface. It is also difficult to remove the groundwater from the DNAPL/alcohol mixture at surface.

Field observations of the Montrose DNAPL mixed with methanol indicated rapid precipitation of DDT. This occurs because the solubility of DDT is higher in chlorobenzene than in alcohol. This precipitate may foul subsurface pores and reduce the effectiveness of an alcohol flooding alternative for the Site. ***Rank: Potentially Effective (but highly uncertain).***

Implementability. This process option is potentially implementable at the Site, although uniform distribution of the alcohol throughout the heterogeneous UBA and subsequent recovery of the alcohol/DNAPL mixture may be problematic. Laboratory studies would be necessary to determine the correct alcohol based on the nature of the DNAPL and site geochemistry. Specialized chemicals and contractors would be required to implement this process option, and regulatory approval of the use of the alcohol would be required prior to injection. Handling of the high concentration alcohols would require special health and safety measures and would need to comply with all regulations governing the handling of flammable liquids. A tracer test would be required to assess the degree of heterogeneity in the saturated zone prior to implementing this process option. ***Rank: Difficult to Implement.***

Cost. The relative cost of this process option is high. The high volumes of alcohol required by this process option would be very costly. ***Rank: High.***

Retain for Assembly of Remedial Alternatives? This process option is not retained for further evaluation partly because high concentration alcohol floods have been infrequently applied as a full-scale remedy at DNAPL sites, and its potential effectiveness has not been demonstrated at a site comparable to the Montrose Site. Although DNAPL mass may be reduced by this process option, DNAPL mobility would be increased rather than reduced, which is not in accordance with DNAPL RAOs. Another limitation is the preferential flow of the alcohols along the coarse-grained portions of the UBA and the potential for severe plugging of the formation and wells. Additionally, this process option is not retained due to the lack of an effective confining layer overlying the BFS and the increased potential for downward mobilization of DNAPL, as compared with other remedial technologies. The uncertainty associated with the potential effectiveness of this process option is very high. ***Retained? No.***

4.5 IN-SITU DESTRUCTIVE TECHNOLOGIES

In-situ bioremediation and chemical oxidation are destructive technologies for transforming or degrading DNAPL into non-toxic end products. These two in-situ destructive technology process options are evaluated in the following sections.

4.5.1 IN-SITU BIOREMEDIATION

In-situ bioremediation is a subsurface process in which microbes are used to convert target organic contaminants, preferably to less toxic compounds. There are two general types of bioremediation: aerobic and anaerobic. Aerobic bioremediation involves microbes that require oxygen to degrade contaminants, whereas anaerobic bioremediation involves microbes that degrade contaminants in an oxygen-free environment. MCB can biodegrade both aerobically and anaerobically, although it is believed that the aerobic biodegradation pathway is faster. The World Health Organization (WHO) indicated in a 2004 publication (WHO, 2004) that "*the less chlorinated benzenes are more readily degraded than the higher chlorinated ones*", and that although "*biodegradation under anaerobic conditions has also been reported, this occurs at a slower rate than aerobic biodegradation*". In-situ bioremediation process options for the unsaturated zone and saturated zone are evaluated separately in the following sections.

Unsaturated Zone (0 to 60 feet bgs)

Process Description. Aerobic bioremediation of compounds in the unsaturated zone is termed "bioventing". Bioventing supplies oxygen to the unsaturated zone to stimulate indigenous aerobic bacteria that degrade the target contaminants. Bioventing is designed to maximize biodegradation of aerobically biodegradable compounds while minimizing removal of compounds by volatilization, which would require ex-situ treatment of contaminated vapors. A bioventing system typically consists of a series of injection wells and blower to introduce atmospheric air into the subsurface at the minimum flow rate necessary to achieve about 4% oxygen by volume or greater in soil gas.

Effectiveness. Bioventing may be effective in biodegrading MCB in the unsaturated zone, although this process option has not been field pilot tested at the Site. Biodegradation of the MCB component of the DNAPL would reduce mass and therefore meet DNAPL RAOs. Although bioventing will not biodegrade the recalcitrant DDT component of the DNAPL, the mobility of the DNAPL in the unsaturated zone, if not already immobile, would be reduced by biodegradation of the MCB component. As the MCB component of the DNAPL is biodegraded (or further partitioned into soil gas for subsequent biodegradation), the DDT component will precipitate, sorb to soil, and become relatively immobile in the environment (DDT tends to sorb strongly to soil). Biodegradation of the MCB component of the DNAPL would be an effective method for reducing the mass and mobility of the DNAPL in the subsurface.

Although bioventing is infrequently implemented at sites impacted with MCB, it has been applied at some sites. At the Dover National Test Site, MCB mass reduction of approximately 77% was observed during one field bioventing experiment. A 1993 laboratory study (Lee and Swindoll, 1993) conducted simultaneous bioventing and SVE experiments of unsaturated soils impacted with a variety of contaminants, including MCB. While both bioventing and SVE were demonstrated to effectively reduce MCB mass, SVE was found to be more effective. The authors concluded that SVE was "*more effective than bioventing for the volatile compounds such as …chlorobenzene and chlorinated aliphatic solvents*".

A key for effective bioventing is the relationship between a compound's biodegradability (represented by its degradation half-life) versus its volatility (represented by its vapor pressure) (EPA, 1995). If the rate of volatilization greatly exceeds the rate of biodegradation, bioventing likely will be less successful because mass transfer from the sorbed phase to the air phase will exceed the rate of biodegradation. The aerobic biodegradation half-life of MCB is relatively long at approximately 150 days [Howard, et. al., 1991]. Therefore, MCB may tend to volatilize rather than biodegrade under a constant delivery of air to the unsaturated zone even though only a minimal air flow would be required to maintain elevated oxygen levels. Additionally, migration of VOCs in soil gas within the unsaturated zone would not be controlled by bioventing (i.e., no SVE).

Application of this technology additionally requires porous, permeable, and unsaturated soils to support air injection. Bioventing is not expected to be effective in the low permeability soils within the PD, although oxygen may slowly diffuse into the PD at a reduced rate as compared with the other unsaturated zone layers. Bioventing is expected to be more effective in the PVS and unsaturated UBA, between 25 and 60 feet bgs, which exhibit higher permeabilities, as long as oxygen can be effectively delivered to these deeper units.

Elevated concentrations of DDT and DNAPL are present within the unsaturated zone and may have detrimental effects on microbial populations. While unsuccessful bioventing applications are rarely due to a lack of microbial activity (EPA, 1995), the presence of DDT and DNAPL in the Site soil could decrease the effectiveness of in-situ bioremediation and would need to be studied. ***Rank: Potentially Effective.***

Implementability. Bioventing is implementable within permeable unsaturated zone soils. Air can be readily injected into permeable soils within the PVS and unsaturated UBA to stimulate aerobic biodegradation of MCB. However, due to the relatively long half-life of MCB, the rate of air injection would need to be carefully managed to prevent uncontrolled migration of MCB vapors in the unsaturated zone. Additionally, bioventing would be more difficult to implement in the low permeability PD soils. ***Rank: Implementable.***

Cost. The relative cost for bioventing in the unsaturated zone is low. ***Rank: Low.***

Retain for Assembly of Remedial Alternatives? In-situ bioremediation is not retained for the unsaturated zone because SVE would be more effective than bioventing in remediating the elevated concentrations of MCB in the unsaturated zone. Although this process option may biodegrade MCB in the unsaturated zone, the rate of aerobic biodegradation is expected to be slower than the rate of volatilization by SVE due to the relatively long half-life of MCB. Additionally, bioventing is infrequently applied to DNAPL-impacted sites. ***Retained? No.***

<u>Saturated UBA (60 to 105 feet bgs)</u>

Process Description: Aerobic bioremediation in the saturated zone involves the addition of oxygen, nutrients, and/or microorganisms to the impacted groundwater to enhance aerobic degradation. The groundwater may be oxygenated using a dilute hydrogen peroxide solution or by aerating the water with air, oxygen-releasing compounds, or pure oxygen. Under aerobic conditions, microbial degradation of VOCs can occur by metabolic or cometabolic transformation reactions (such as using methane to stimulate the growth of methanotrophs).

Anaerobic bioremediation requires the addition of electron donors, such as lactate or ethanol, to dechlorinate the dissolved contaminants. Anaerobic bioremediation primarily occurs under reducing conditions (a redox reaction) that requires electron donors for dechlorination (i.e., replacement of the chlorine atom with a hydrogen atom). Reductive dechlorination is the principal mechanism for anaerobic biodegradation of most highly chlorinated VOCs such as TCE and PCE. Anaerobic bioremediation can be implemented as a passive technology, such as injection of an emulsified vegetable oil, or as an active technology with groundwater extraction, electron donor addition, and re-injection of the amended groundwater.

Effectiveness. This in-situ bioremediation process option is potentially effective in the saturated UBA. Biodegradation of the MCB component of the DNAPL may reduce both mass and mobility over time and would meet DNAPL RAOs. Although this process option will not biodegrade the recalcitrant DDT component of the DNAPL, the mobility of the DNAPL in the saturated zone may be reduced by biodegradation of the MCB component. If the MCB component of the DNAPL is biodegraded, the DDT component will precipitate, sorb to soil, and become relatively immobile in the environment (DDT tends to sorb strongly to soil). Biodegradation of the MCB component of the DNAPL is uncertain but could potentially be an effective method for reducing the mass and mobility of the DNAPL in the subsurface.

Laboratory microcosm studies have demonstrated the potential effectiveness of aerobic biodegradation of dissolved-phase MCB at lower concentrations. Although not impacted with DNAPL, a 1997 microcosm study using UBA soils and groundwater demonstrated a 38% reduction in MCB after 4 weeks under aerobic conditions (Zeneca, SPEL, 1997). This microcosm study demonstrates the potential effectiveness of aerobic bioremediation at the Site, although since dissolved-phase MCB concentrations will be 10 to 30 times higher in the DNAPL-impacted area, additional microcosm studies would be required to verify effective MCB biodegradation under high concentration conditions. If the microcosm experiments demonstrate the feasibility of biodegrading MCB in-situ under these conditions, then a field pilot test would be required to verify the effectiveness in the field and obtain preliminary biodegradation rates and biological oxygen demand for full-scale design.

The 1997 microcosm experiments were conducted without the need for microbial augmentation of MCB-degrading bacteria. Therefore, naturally occurring bacteria at the Site may be adequate to support an aerobic in-situ bioremediation component of the RA. However, if microbial populations are low, then bioaugmentation would additionally be required as part of the in-situ bioremediation remedy component, although bioaugmentation is not always successful.

This technology has been infrequently applied at DNAPL sites (or suspected DNAPL sites). The majority of applications were anaerobic bioremediation projects at sites impacted with chlorinated ethenes such as dichloroethylene (DCE) isomers, TCE, or PCE, which are more common environmental contaminants as compared to MCB, which is relatively uncommon. Other studies and reference documents addressing in-situ bioremediation of DNAPL-impacted areas include:

- In a 2004 paper (Geosyntec, 2004), Geosyntec Consultants reported that dechlorinating microorganisms are not inhibited by dissolved concentrations approaching the solubility limit, and therefore, anaerobic degradation is a process option that is applicable to TCE or PCE DNAPL source areas.

- In a 2003 study (McCarty, et.al., 2003), the authors demonstrated that reductive dechlorination in the presence of a TCE, PCE, or carbon tetrachloride DNAPL was possible. Reductive dechlorination was additionally found to increase the rate of DNAPL dissolution (into groundwater), which serves to accelerate the rate of biodegradation. However, it is noted that anaerobic bioremediation of MCB has been infrequently studied or field pilot tested.

- Reductive dechlorination of chlorinated benzenes, among other chemicals, by various strains of Dehalococcoides is currently being studied by Dr. Stephen Zinder at Cornell University. Bioaugmentation of naturally occurring microorganisms with MCB-degrading bacterial strains may be an effective method for enhancing the rate of anaerobic biodegradation at the Site but is uncertain. Bioaugmentation using various strains of Dehalococcoides is a widely used enhancement for this bioremediation process option.

- In-situ bioremediation can be implemented as a primary, stand-alone remediation technology or as a secondary technology, following a more aggressive primary remediation technology. In a 2004 paper, Geosyntec Consultants indicated that in-situ "*bioremediation can work synergistically with other DNAPL treatment technologies…to speed up DNAPL treatment, or be used as a polishing step to cost effectively remove residual DNAPL left behind from more aggressive technologies*." The compatibility of in-situ bioremediation with another technology would require evaluation and bench-scale testing, at a minimum, but this approach has been used at some DNAPL sites.

- In a 2005 paper (Christ, et.al., 2005), the authors evaluated coupling in-situ bioremediation with more aggressive DNAPL mass removal technologies, although only anaerobic reductive dechlorination was evaluated for highly chlorinated ethenes (e.g., TCE, PCE). The authors noted that following aggressive mass removal technologies, "*some DNAPL will likely remain within the porous medium even when treatment is most effective*", and that "*application of such technologies may not substantially reduce risk and could potentially worsen site conditions (e.g., through mobilization and redistribution of DNAPL…)*".

Based on review of available data, Site conditions range from aerobic to anaerobic, with anaerobic conditions prevailing in areas with high MCB concentrations. Therefore, distribution of oxygen in the subsurface would be critical to the effectiveness of an aerobic bioremediation process option. Like many other process options, the heterogeneous nature of the UBA may reduce the effectiveness of this process option due to non-uniform distribution, particularly in lower permeability areas. A relatively high density of wells may be required to effectively deliver oxygen and mineral nutrients throughout the DNAPL-impacted UBA. Additionally, a portion of the oxygen may be consumed by other organics or minerals within the UBA during remedy implementation. Therefore, sufficient oxygen must be delivered to overcome the natural oxygen demand of the UBA and support in-situ aerobic bioremediation.

Additional bench-testing would be required to verify that MCB-degrading bacteria would not be significantly inhibited in the presence of DNAPL-phase MCB (i.e., high concentrations of MCB). A study performed by Fritz, et. al (1991) evaluated the sensitivity of a particular MCB-degrading strain, RHO1, to high concentrations of MCB. The study showed that MCB concentrations higher than approximately 394,000 µg/L were toxic to *Pseudomonas* species strain RHO1. MCB concentrations at or near the solubility limit (approximately 500,000 µg/L) are expected near the DNAPL-water interface at the Site and may inhibit biodegradation of MCB in the immediate vicinity of the DNAPL. While the RHO1 strain of *Pseudomonas* species is not the only MCB-degrading bacteria, these findings suggest that a bench test may be required to evaluate whether MCB-degrading bacteria present at the Site would be inhibited by high MCB concentrations approaching the solubility limit.

Similarly, the DDT component of the DNAPL may also have detrimental effects on MCB-degrading bacteria and could lessen the effectiveness of this bioremediation process option. In-situ bioremediation may be more effective in areas where DNAPL saturations and contaminant concentrations are lower. The potential effectiveness of this technology to biodegrade the MCB component of the DNAPL is highly uncertain in the absence of comparable microcosm studies or field pilot tests. ***Rank: Potentially Effective (but uncertain).***

Implementability. This bioremediation process option is implementable and would require groundwater extraction wells, an oxygen and mineral nutrient amendment system, and groundwater re-injection wells. Hydrogen peroxide and mineral nutrients are readily available chemicals and could be added to groundwater prior to re-injection to stimulate in-situ aerobic biodegradation of MCB. However, the heterogeneous nature of the UBA will impede uniform distribution of the oxygen and amendments, but these effects could largely be offset by a higher density of extraction/injection wells. A relatively low level of maintenance is required to implement this process option, and highly skilled field operators are not required. Some of the bioremediation amendments, such as hydrogen peroxide, can require special safety and handling procedures depending on the relative strength of the source chemical. Additionally, routine redevelopment of the extraction/injection wells may be required to restore hydraulic conductivities reduced by biofouling. ***Rank: Implementable.***

Cost: The relative cost for in-situ bioremediation is medium. The duration of an in-situ bioremediation process option would be relatively long due to the high DNAPL mass present in the saturated UBA, however, long-term hydraulic containment will be required at the Site regardless which remedial alternative is selected. ***Rank: Medium.***

Retain for Assembly of Remedial Alternatives? Given the large DNAPL mass present in the saturated UBA and other complexities associated with the Site, implementation of in-situ bioremediation as a primary remediation technology would require a long duration. Additionally, the potential effectiveness of in-situ bioremediation to reduce DNAPL mass is uncertain and has not been demonstrated at a comparable site. Hence, additional laboratory testing would be required simply to demonstrate the feasibility of biodegradation at the elevated MCB concentrations present at the Site.

If the microcosm experiments were successful, then a field pilot test would be required to determine the potential effectiveness of this technology at the Site and within the heterogeneous UBA. In-situ bioremediation is a technology that primarily addresses reduction of dissolved-phase contaminants, and it is uncertain whether such reduction would occur at rates sufficient to significantly impact DNAPL mass. This process option is not retained for further evaluation. ***Retained? No.***

4.5.2 IN-SITU CHEMICAL OXIDATION

Process Description. In-situ chemical oxidation (ISCO) involves the injection of chemical oxidants into the DNAPL-impacted zone to destroy dissolved-phase constituents and DNAPL. The process is achieved by injecting an oxidant mixed with water into the treatment zone via a series of injection wells. Once in the subsurface, oxidants are transported by advection, dispersion, and diffusion to reach the targeted contaminants. Common oxidants used for groundwater remediation include potassium permanganate, sodium permanganate, persulfate, peroxide, ozone, and Fenton's solution. The strong oxidants will react with most organic compounds and cause the contaminants to degrade into non-toxic end products. Under this process, the contaminants are destroyed in-situ and are not extracted for ex-situ recovery or treatment. Sufficient oxidant solution must also be injected to overcome the natural oxidant demand of the aquifer solids. Depending on the mineralogy and the amount of naturally occurring organic carbon, the oxidant demand can exceed the demand of the contaminant.

Effectiveness. This process option is potentially effective but has not been bench or field pilot tested at the Site. This process option would meet DNAPL RAOs by reducing DNAPL mass, which in turn reduces its mobility. ISCO has been applied at a number of DNAPL sites with increasing frequency, although none with the estimated in-situ mass comparable to the Montrose Site. The Arkema Site in Portland, Oregon is also impacted with an MCB/DDT DNAPL, a former DDT manufacturer, and has pilot tested an ISCO process option using sodium persulfate for groundwater remediation. MCB concentrations in groundwater were reduced during the test but rebounded quickly. In spite of the marginal pilot test results, Arkema is pursuing ISCO as an interim remedial measure for groundwater at the site. However, the volume of DNAPL at that site is significantly below the amount estimated to be present in the saturated UBA beneath the Montrose Site, and the potential effectiveness of this in-situ destruction process option is uncertain.

A primary advantage of this process option is destruction of the contaminants, rather than extraction and capture. Additionally, an ISCO alternative can be implemented in a relatively short time period because the oxidation reaction is fast compared to other technologies, such as in-situ bioremediation. However, the effectiveness of ISCO at the Site is limited by the same factors that limit the use of surfactants, cosolvents, or any other remedial technology which relies on uniform distribution in the subsurface. The oxidants must come in physical contact with the DNAPL to be effective, and heterogeneities within the UBA will limit the ability to control the distribution of oxidant into the DNAPL-impacted zone. Additionally, naturally-occurring organic matter in the soil would be oxidized, thereby decreasing the effectiveness of this process option and increasing the oxidant demand. Some reaction products of oxidation, like precipitation of manganese oxide in the case of permanganate, can reduce soil permeability leading to inefficient distribution of the oxidants. Additionally, precipitation of inorganics due to pH and/or redox changes may result in plugging of the formation. ***Rank: Potentially Effective (but uncertain).***

Implementability. An ISCO process option is potentially implementable at the Site. Liquid-phase oxidants can be injected into the saturated UBA via injection wells, although mobile DNAPL may be displaced during injection. This technology does not require an aboveground treatment system, and would not generate a large volume of waste materials during the field application. This process option requires skilled operators and technology vendors. The oxidizing agents pose a safety hazard to site workers and must be handled with care. Depending on the rate of oxidation, implementation of an ISCO process option can additionally result in elevated concentrations of carbon dioxide being released from the saturated zone into the unsaturated zone (posing surface exposure hazards at some sites). ***Rank: Implementable.***

Cost. The relative cost of ISCO application would be high due to the large mass of DNAPL present in the saturated UBA. Material cost for oxidants would be high and multiple rounds of oxidant injection would be required to appreciably reduce the DNAPL mass. ***Rank: High.***

Retain for Assembly of Remedial Alternatives? This remedial technology is not retained for further evaluation because an exceptionally large quantity of oxidants would be required to treat the estimated DNAPL mass in the saturated UBA. Additionally, the potential effectiveness of ISCO is uncertain and partly because it has not been demonstrated at the Site through bench or field pilot testing. ***Retained? No.***

4.6 IN-SITU THERMAL TECHNOLOGIES

Three separate in-situ thermal treatment process options are evaluated in this section, electrical resistance heating (ERH), thermal conductive heating (TCH), and steam injection. These process options heat the subsurface and remediate DNAPL by vaporization (of the MCB component), oxidation, or flushing. Each of the candidate thermal process options are evaluated against the three preliminary performance criteria in the following sections.

4.6.1 ELECTRICAL RESISTANCE HEATING

Process Description. ERH is an in-situ technology for vaporizing DNAPLs. This is accomplished by installing electrodes throughout the treatment zone and transmitting an electric current between them to heat the soil by electrical resistance. The electrodes are typically spaced from 12 to 25 feet apart depending upon soil resistivity. The vapors generated by this process option are then recovered by SVE for ex-situ vapor treatment as evaluated in Section 4.8. The ERH process benefits from the co-boiling of DNAPL VOCs at temperatures below the boiling point of groundwater. Co-boiling allows reduction of the DNAPL VOC contaminants without having to boil off all of the groundwater, which would otherwise reduce the electrical conductivity and power delivery to the saturated zone. Electrodes are installed in the target treatment interval within soil borings drilled using standard methods. The electrodes are typically constructed using highly conductive materials, such as steel shot, and are limited in effective length. Treatment of intervals thicker than 16 feet may be accomplished by stacking electrodes in the same borehole. In order to prevent a loss of conductivity, water is circulated within the electrode via a drip line. Some of the technology vendors hold patents for electrode design elements and operation.

Three commercially ERH process options are available:

- Three-phase heating (Thermal Remediation Services); Three-phase heating uses three-phase electrical power with one phase delivered to each of three electrodes positioned in a triangular pattern.

- Electro-Thermal Dynamic Stripping Process (ET-DSP™; McMillan-McGee); The ET-DSP™ process option uses a patented and pre-fabricated electrode, which is subsequently installed within a soil boring (as opposed to constructing the electrode in the field). Unlike the other ERH technologies, ET-DSP™ injects water for the purpose of dynamic (steam) stripping of the contaminants.

- Six-phase heating (SPH; Current Environmental Solutions); SPH splits a three-phase power source into six phases with one phase delivered to each of six wells positioned in a hexagonal pattern.

Effectiveness. ERH has not been implemented at a site comparable to Montrose, and therefore, its potential effectiveness is uncertain. ERH has never been applied to a DNAPL site where either MCB or DDT was a primary component of the DNAPL. The co-boiling point for the Montrose DNAPL (with water) is 96°C, which approaches the upper limit of potential effectiveness for ERH (i.e., 100°C). ERH has been most frequently implemented at sites impacted with TCE, which has a much lower co-boiling point of 73°C (and a boiling point of 87°C). The effectiveness of ERH to thermally treat soils impacted with an MCB DNAPL has never been demonstrated at either pilot or full-scale.

In a 2007 evaluation (CH2M Hill, 2007), EPA reported the largest ERH treatment area conducted to date at approximately 44,000 square feet (Fort Richardson site in Anchorage, Alaska) and the largest ERH treatment volume at approximately 80,000 cubic yards (Savannah River site in Aiken, South Carolina). CES additionally conducted SPH at a former manufactured gas plant (MGP) site in Bloomington, Illinois over an area of approximately 91,000 square feet, but the treatment depth was less than 20 feet (treatment volume of approximately 60,000 cubic yards). A full-scale ERH remedy is currently being implemented at the Paducah Gaseous Diffusion Plant over an area of 22,000 square feet and volume of 80,000 cubic yards. The average ERH treatment area and volume are significantly smaller than the dimensions of the entire DNAPL-impacted soils at the Montrose Site. Based on a review of full-scale ERH sites (Earth Tech, 2007c), the average treatment area and volume were approximately 17,000 square feet and 22,000 cubic yards.

If ERH were applied over the entire DNAPL-impacted area at the Montrose Property, it would be the largest ERH project ever implemented in the United States. The entire DNAPL-impacted UBA covers an area of approximately 160,000 square feet and over a saturated interval of 45 feet. The target treatment volume at the Montrose Property would be approximately 267,000 cubic yards. There are no comparable sites where ERH has been implemented. Considering the thickness of the treatment interval, the unusual nature of the Montrose DNAPL, and the heterogeneous nature of the saturated UBA, ERH at the Montrose Site would likely be the most complicated thermal remediation project, if undertaken. The DNAPL architecture is changed by thermal remediation, increasing the importance of fully understanding the DNAPL distribution (and movement) so that all mobilized contaminants can be effectively recovered. Otherwise, contaminant spreading or downward migration could result, thereby exacerbating the DNAPL distribution instead of reducing its mobility and mass.

Factors affecting the potential effectiveness of ERH at the Montrose Site include:

- The resistivity of the soils in the treatment area. Highly resistive soils will inhibit the transmission of electricity and reduce the effectiveness of ERH. Desaturated soils, due to boiling of the groundwater, can yield higher resistivity soils that can result in inefficient and non-uniform heating of the treatment zone. The relative high co-boiling point of the Montrose DNAPL (96°C), only 4°C below the boiling point of water (at 1 atmosphere), increases the potential for desaturation to occur during ERH implementation. Desaturation of soils surrounding the electrodes reduces the transmission of electrical current and is a common performance problem at ERH sites.

- Additionally, water influx from the surrounding formation or underlying layers can result in cooling, requiring additional energy and longer treatment times in order to achieve and sustain a temperature above the co-boiling point. In the presence of upward vertical gradients, underlying aquifers can cool the base of the thermal treatment zone and pose significant challenges to effective heating by ERH. Non-uniform heating and water influx have been the primary reasons reported at other sites for reduced effectiveness of ERH.

- Another effectiveness issue related to ERH is treatment interval thickness. ERH is less applicable to thick saturated treatment intervals. The electrical current from the electrodes tends to be highest at the poles (ends). A long electrode, greater than 10 feet in height, may not effectively heat soils in the middle of the treatment interval. For this reason, multiple electrodes must be stacked for thick treatment intervals, contributing to the complexity of the process option and providing a greater opportunity of non-uniform heating. A treatment interval of 30-feet or less is typically implemented at ERH sites.

  At the Montrose site, the 45-foot thickness of the DNAPL-impacted UBA may therefore pose significant challenges for effective and uniform heating by ERH. Achieving target temperatures at depth within the saturated zone has proven to be problematic at several ERH case sites. An example is the Paducah Gaseous Diffusion Plant in Kentucky. Soil temperatures of only 30°C to 70°C were achieved between 95 and 105 feet bgs at the Paducah Site because the thick treatment interval resulted in poor performance of the deep electrodes. The excessive weight of the steel shot backfill resulted in structural failure of the insulating materials used to separate each of six electrical elements. The electrodes functioned as a single element with no vertical differentiation, and as a result, were not effective in heating the deeper soils.

  ERH has also not been implemented at depth and over thick saturated intervals at sites that are comparable to Montrose. The Pemaco Superfund Site has been identified as a site where ERH was applied over a thick saturated zone (CH2M Hill, 2007), but that site is not comparable to the Montrose Site for the reasons identified in Appendix L and summarized as follows:

  > <u>Pemaco Superfund Site:</u> ERH was implemented over an area of 14,000 square feet and from 35 to 95 feet bgs. The saturated thickness at this site was 35 feet, from 60 to 95 feet

bgs. However, no DNAPL was present at this site. The thermal remediation primarily addressed dissolved-phase TCE, and less than 100 pounds of TCE was removed during the thermal remedy. Furthermore, the target temperature was not reached throughout the treatment zone due to non-uniform heating, primarily from asymmetrical electrode spacing, low efficiency of long electrodes, and slanted electrodes located on the east side of the treatment area.

- Although the heterogeneous nature of the saturated UBA may not inhibit heating by ERH, it may reduce the effectiveness of recovering volatilized contaminants by SVE. The extraction system efficiency is critical for a successful ERH remedy, and VOCs that are not effectively recovered will cool and re-condense in the subsurface.

The potential for downward mobilization is another concern associated with thermal treatment technologies, although less problematic for ERH than some other thermal technologies, specifically steam injection. Heating reduces the viscosity and interfacial tension of the DNAPL, increasing its mobility in the short-term, which is not consistent with DNAPL RAOs. Although ERH relies exclusively on vaporization, rather than DNAPL mobility, unrecovered VOCs can condense in other areas of the saturated UBA, potentially posing an increased risk of downward migration. Heating of the underlying hydrologic unit, known as a "hot floor", was implemented at 6 ERH sites in an attempt to reduce the potential for downward mobilization during thermal remediation. However, 2 of the 6 attempted hot floors were not successful in reaching target temperatures. At the Westside Corporation site in Queens, New York (a PCE site with no DNAPL), target temperatures were not reached in the hot floor due to influx of cool groundwater. Similar conditions were experienced at the Gaseous Diffusion Plant site in Paducah, Kentucky (a TCE DNAPL site), where hot floor temperatures only reached to between 30 and 70°C. ***Rank: Potentially Effective (but uncertain).***

Implementability. Although three qualified ERH vendors (TRS, CES, and MC2) are available, this process option would be difficult to implement. A significant amount of complex above- and below-ground infrastructure would be required to generate and deliver electricity throughout the DNAPL-impacted area. An exceptionally large number of electrodes would be required to treat the entire DNAPL-impacted area and would generate a significant amount of waste requiring management and disposal. This process option would additionally require implementation of SVE to recover VOCs for ex-situ vapor treatment. This process option requires skilled operators and a high level of maintenance. ERH is an energy-intensive remedial technology, and the amount of energy required to heat the entire DNAPL-impacted area would be enormous. The resulting carbon footprint for a full-scale ERH remedy would be similarly large and not in accordance with EPA green remediation initiatives. ***Rank: Difficult to Implement.***

Cost. The relative cost for this thermal technology process option is very high. High costs are incurred for not only electrode and multiphase extraction well installation, but also waste disposal and electricity consumption. This process option requires both soil vapor and groundwater extraction, resulting in high ex-situ treatment costs. If a hot floor is implemented as a component of the ERH remedy, costs for this process option are further increased. ***Rank: Very High.***

Retain for Assembly of Remedial Alternatives? The potential effectiveness of this process option is highly uncertain given the Site conditions and unique nature of the Montrose DNAPL. Additionally, the potential effectiveness of this thermal technology has not been demonstrated through bench or field pilot testing. Despite its technical uncertainties, implementability challenges, and high cost, EPA has indicated a desire to evaluate candidate thermal remediation technologies in this FS. Although Montrose does not agree, ERH is retained for further evaluation as requested by EPA and based on its potential effectiveness in reducing DNAPL mass and mobility by vaporizing the MCB component of the Montrose DNAPL. ***Retained? Yes.***

4.6.2 THERMAL CONDUCTIVE HEATING

Process Description. In-Situ Thermal Destruction (ISTD) is a commercially available thermal conductive heating process option offered by TerraTherm, Inc. Under this process, conductive heating wells are installed throughout the target treatment zone and spaced approximately 6 to 20 feet apart. The heating wells are typically positioned in a hexagonal pattern with six heating-only wells positioned around one central heater-vacuum well (i.e. 7-spot pattern). Electrically-powered heating elements are positioned in the wells to coincide with the target thermal remediation zone. The elements are heated to elevated temperatures between approximately 650 and 800°C, and heat is transferred conductively from the wells to the surrounding formation. Contaminants in close proximity to the heater wells are oxidized in-situ to carbon dioxide, water vapor, and acid gas (if a chlorinated VOC). Contaminants which are not directly oxidized are instead vaporized and withdrawn from the subsurface using SVE. A vacuum is applied to the heater-vacuum wells to extract soil vapors and volatilized contaminants from the subsurface. During the extraction process, soil vapors pass across the heating elements, thereby partially oxidizing the vapor-phase contaminants. The partially oxidized VOCs, steam, and acid gas are then extracted for aboveground treatment. The vapors exiting the heater-vacuum wells are cooled to condense the steam, scrubbed to neutralize the acid gas, and then finally treated to remove any residual vapor-phase contaminants using standard methods as evaluated in Section 4.8.

Effectiveness. This conductive heating process option will not be effective in remediating the Montrose DNAPL. While the MCB can be treated by this process option, a portion of the DDT will additionally be oxidized resulting in the generation of an excessive amount of acid gas that will corrode metal piping and equipment. In March 2002, ISTD was implemented at the Rocky Mountain Arsenal site located in Denver, Colorado to treat soils impacted with organochlorine pesticides. However, after just 12 days of operation, thermal remediation activities were terminated due to severe corrosion of the piping and equipment (EPA, 2006). The high chlorine content of the pesticides generated an excessive amount of hydrochloric acid gas, which corroded portions of the piping and aboveground vapor treatment equipment beyond repair. TerraTherm concluded that ISTD was not applicable to soils impacted with highly chlorinated pesticides, such as DDT. ***Rank: Not Effective.***

Implementability. This conductive heating process option is not implementable at the Site due to the high chlorine content of the Montrose DNAPL (combined MCB and DDT). ***Rank: Not Implementable.***

Cost. The relative cost of this conductive heating process option is very high. ***Rank: Very High.***

Retain for Assembly of Remedial Alternatives? This process option is not retained for further evaluation due to the incompatibility of the remedial technology with the high chlorine content of the Montrose DNAPL. ***Retained? No.***

4.6.3 STEAM INJECTION

Process Description. Patented steam injection processes, including Dynamic Underground Stripping (DUS) and Steam Enhanced Extraction (SEE), have been available for site remediation since 1991. Under these processes, pressurized steam is injected into the subsurface to vaporize contaminants for recovery by SVE. The steam will condense in the subsurface and can additionally displace or flush contaminants towards recovery wells at the condensate front. The increased heat may also cause a decrease in the DNAPL viscosity and interfacial tension, thereby increasing the mobility of the contaminant. A series of steam injection and multi-phase extraction wells are positioned throughout the DNAPL-impacted zone to optimize steam delivery and contaminant recovery, typically in 5-spot or 7-spot patterns. Vapor-phase contaminants are removed by SVE and liquid-phase contaminants (groundwater, DNAPL, and steam condensate) are removed by direct extraction. DNAPL is separated from the groundwater/steam condensate and disposed off-Site. Soil vapors are treated by the process options evaluated in Section 4.8, and groundwater is treated by the process options evaluated in Section 4.7. A steam boiler or steam generator is required to implement this process option.

Effectiveness. Steam injection has not been pilot tested at the Site, and its potential effectiveness is highly uncertain. Steam injection has been implemented at DNAPL-impacted sites in the past, although never at a site comparable to Montrose and much less frequently in recent years. ERH or TCH are the predominant thermal technologies being employed today, and currently, there are only two active full-scale steam injection sites in the United States, the Pacific Wood Treating Site in Port of Ridgefield, Washington and the Savannah River M Settling Basin Site in Aiken, South Carolina. The two primary reasons why steam injection is less frequently implemented than the other thermal technologies are as follows:

- Permeable Soils: Permeable soils are required to deliver steam to the DNAPL-impacted area, and steam will preferentially flow through higher permeability soil layers. Lower permeability soil layers will receive a reduced steam injection rate or no steam. Heating of low permeability soils may be problematic and reliant on thermal heat conduction from adjacent sand layers. By comparison, ERH and TCH are less dependent on soil permeability for heating and are more frequently implemented today.

- Steam Condensate/Downward Mobilization: Injected steam will condense in the subsurface and must be recovered for ex-situ treatment. Under a steam injection process option, there is an increased potential for downward mobilization of DNAPL or dissolved-phase contaminants in steam condensate. As the steam front expands in the DNAPL-impacted zone, a buildup of DNAPL occurs at the edge of the steam front. Because the mobility of DNAPL is highly dependent on the saturation of DNAPL, this increase in DNAPL saturation at the edge of the steam front will lead to an increased potential for vertical mobilization of the DNAPL to a greater degree than for all other RAs presented. Desaturation of confining layers or capillary barriers could additionally lead to downward migration. Downward mobilization through a desaturated capillary barrier was observed during 2-dimensional bench-scale testing as indicated in Section 2.6.5. It was also observed during 2-dimensional bench-scale testing conducted for the Solvents Recovery Services of New England site (She and Sleep, 1999). Downward mobilization of DNAPL could exacerbate the environmental impacts rather than mitigate them. By comparison, ERH and TCH rely primarily on contaminant vaporization, rather than mobilization.

A fundamental issue related to the effectiveness of a steam injection remedy is steam distribution. Steam will preferentially flow along the path of least resistance, and uncontrolled steam distribution can result in spreading of the contamination within the saturated zone. Within the saturated UBA, DNAPL extends to the northern Property boundary. Uncontrolled steam distribution near the northern Property boundary has the potential to result in displacement of DNAPL, vapor-phase MCB, or dissolved-phase MCB away from the treatment area and potentially under the adjacent industrial building (located on the former Boeing Realty Company property). This type of contaminant spreading, if it were to occur, would not meet the DNAPL RAOs and would reduce the effectiveness of this process option.

Another issue related to the potential effectiveness of a steam injection remedy is steam over-ride, where steam rises (due to buoyancy effects) to the top of a permeable sand layer, thereby by-passing DNAPL accumulated at the bottom of the sand layer. In a heterogeneous environment such as the saturated UBA, steam flow will predominantly be in the lateral direction within the sand layers. Steam over-ride along the top of the sand layer is a potential inefficiency in flushing DNAPL which is pooled along the bottom of the sand layers. This inefficiency is most predominant in thicker sand layers.

Steam injection has never been applied to a DNAPL site where either MCB or DDT was a primary component of the DNAPL. The relatively high co-boiling point of the Montrose DNAPL (96°C) would likely result in reduced mass removal efficiencies as compared with VOCs with lower co-boiling points, such as TCE (73°C). For example, during steam injection pilot testing at the Savannah River Site in Aiken, South Carolina, the initial rate of TCE mass removal was significantly higher than the initial mass removal rate for PCE (which has a co-boiling point of 88°C), even though the DNAPL was primarily composed of PCE (approximately 90% PCE and 10% TCE; co-boiling point of PCE/TCE/water mixture would be <88°C). The effectiveness of steam injection to thermally treat soils impacted with an MCB DNAPL has never been demonstrated at either pilot or full-scale.

If steam injection were applied over the entire DNAPL-impacted area at the Montrose Property, it would be one of the four largest steam injection projects ever implemented in the United States. Four of the largest steam injection projects implemented to date include:

- The SCE Pole Yard Site in Visalia, California (remedy completed)
- The AG Communications Site in Northlake, Illinois (remedy completed)
- The Savannah River Site M Area Settling Basin in Aiken, South Carolina (on-going)
- The Pacific Wood Treating Site in Port of Ridgefield, Washington (being implemented in two phases)

However, there are, in fact, numerous fundamental differences between these sites and the Montrose Site as described in Section 5.2.6, Appendix L, and discussed in part as follows:

Contaminant: The primary contaminants at the SCE Visalia site were creosote (with pentachlorophenol) and diesel fuel. SCE reported that the creosote became an LNAPL at temperatures greater than 50°C, and therefore, the physical properties of the primary contaminants are fundamentally different from the Montrose Site, with no significant risk of downward migration. There was no DNAPL present at the AG Communications site, which was primarily impacted with dissolved concentrations of TCE, cis-1,2-DCE, benzene, and xylenes. The maximum pre-remediation TCE concentration in groundwater at the AG Communications site was 20,000 ug/L, which is only 1.8% of the solubility limit and increased to 45,000 ug/L following the start of steam injection.

Lithology: At the SCE Visalia site, steam was injected into the Intermediate Aquifer from 80 to 100 feet bgs, which was described as a medium to coarse-grained sand with some gravel. At the Savannah River Site, steam was injected into the M-Area Aquifer, which had a saturated sand thickness of 25 to 30 feet. The lithology at both of these sites is far more suited to steam injection than the layered and highly heterogeneous lithology of the saturated UBA at the Montrose Site (sequences of thin sands interbedded with layers of silt). At the AG Communications site, the majority of the steam injection wells were screened in the unsaturated zone to enhance SVE operations due to low permeabilities of $9x10^{-8}$ to $1x10^{-8}$ cm/sec. The steam injection wells that were completed in the saturated zone only extended between 6 and 8 feet below the water table.

Treatment Area: Although SCE reported steaming an area of approximately 155,000 square feet (including area outside the perimeter steam injection wells), the actual target treatment area was much smaller. Eleven (11) steam injection wells were located outside the perimeter of the treatment area. The area inside the steam injection wells was approximately 100,000 square feet, and the target treatment area was even smaller at approximately 80,000 square feet, which is half the size of the DNAPL-impacted area at the Montrose Site. The treatment area and volume was mis-reported for the AG Communications site as 250,000 square feet and 330,000 cubic yards respectively. However, in fact, the sum of the two treatment areas at the AG Communications site was approximately 80,000 square feet, resulting in combined treatment volume of approximately 85,000 cubic yards.

Steam Injection Rate: At the SCE Visalia site, steam was injected at a combined rate up to 200,000 lbs/hr into 11 wells (average of 15,000 to 20,000 lbs/hr per well). The conceptual full-scale steam injection rate for the Montrose Site (as described in Section 5.1.6) was reduced from 60,000 to 40,000 lbs/hr following EPA comments on preliminary remediation cost estimates (into a minimum of 48 wells). Lower steam injection rates may result in reduced MCB mass removal efficiencies. At the AG Communications site, steam was injected at low pressures of only 3 to 7 psig. By comparison, steam was injected at 38 psig at Visalia and would be injected at approximately 20 psig at the Montrose Site.

<u>Pore Volumes/Energy Consumption:</u> SCE has reported that "approximately 8" pore volumes of steam were flushed through the Intermediate Aquifer during the steam remedy at the Visalia site. At the Savannah River Site, more than 2.5 times more steam was required than originally expected based on computer modeling. Steam was injected into the primary sand aquifer (M-Area Aquifer) over a period of 3.3 years to thermally remediate a DNAPL composed primarily of PCE (co-boiling point of <88°C). Had steam injection been terminated at the target energy demand, less than 60% of the DNAPL removed to date would have been recovered from the site. The mass removal efficiency would, of course, be less than 60%. By comparison, the number of steam pore volumes assumed for the Montrose Site was reduced to between 2 and 3 following EPA comments on preliminary remediation cost estimates. However, lower energy and steam delivery to the saturated UBA will result in lower reductions in DNAPL mass/volume. If up to 8 pore volumes of steam flushing are required at the Montrose Site, then the already high steam remedy costs assuming only 2 to 3 pore volumes of flushing would be greatly understated. The Montrose Site, given the heterogeneous UBA and complicated DNAPL architecture, may require more pore volumes of steam flushing than the SCE Visalia Site, not less.

<u>Contaminant Recovery:</u> SCE recovered between 130,000 and 150,000 gallons of liquid-phase creosote, which was more than double the volume originally estimated as being in-situ. The majority of the contaminant mass was removed as liquid-phase NAPL. Smaller percentages were recovered in the vapor-phase, dissolved-phase, or destroyed in-situ (estimated). By comparison, the majority of the DNAPL mass removal at the Montrose Site would be in the vapor-phase (i.e., the MCB component of the DNAPL). While an estimated 425,000 pounds of VOCs has been removed at the Savannah River Site, they are unable to reliably estimate the percent of DNAPL mass removed or residual concentrations/saturations. The original estimate of existing contaminant mass at the Savannah River Site was 2 million pounds, but it may have been overestimated. Post-remediation soil samples are not scheduled to be collected until the treatment zone cools down, and therefore, the technical effectiveness of the thermal remediation has yet to be determined and is uncertain. At the AG Communications Site, only 33,000 pounds of VOCs were removed over a period of 4.2 years. No liquid-phase DNAPL was recovered, and steam

injection was implemented to remediate dissolved-phase contamination and enhance SVE within a low permeability unsaturated zone.

Hot Floor: At the Savannah River Site, the M-Area Aquifer is underlain by a low permeability clay (the Green Clay), which serves as a capillary barrier preventing further downward migration of the PCE DNAPL. As a result, a hot floor was not implemented or required at the Savannah River Site. Although steam was injected into the Deep Aquifer at the SCE Visalia site, the purpose was to prevent continued influx of cool groundwater into the thermal treatment zone and not to mitigate the potential for downward migration. Furthermore, only a small portion of the underlying Deep Aquifer at the SCE Visalia site was heated using just 3 steam injection wells. At the Montrose Site, a 20 to 25 foot thick sand aquifer (the BFS) underlies the DNAPL-impacted UBA and would require heating over the entire thermal treatment area.

DNAPL Displacement: CH2M Hill has indicated displacement of liquid-phase DNAPL as an advantage for steam injection over other thermal technologies (CH2M Hill, 2007). However, at the Savannah River Site, less than 0.1% of the DNAPL mass was recovered in liquid-phase; greater than 99.9% of the mass recovered was in the vapor-phase. Therefore, this advantage appears to be overstated.

A hot floor created by steam injection into underlying hydrologic layer can be applied in the BFS in an attempt to reduce the potential for downward mobilization. However, the potential effectiveness of a hot floor is highly uncertain and implementation of a hot floor presents its own increased risk of downward mobilization. Hot floors are very infrequently implemented, and the effectiveness of a steam injection hot floor in reducing downward mobilization has not been reliably demonstrated in the field. In the limited number of cases where a hot floor was implemented, ERH or TCH was typically used to heat the hydrologic layer underlying the DNAPL-impacted zone. In only one case (the SCE Site in Visalia, California), steam injection was implemented in an underlying aquifer unit to heat an overlying DNAPL-impacted aquitard. For that case, and as indicated above, steam was injected into the underlying aquifer during a subsequent treatment phase to reduce the upward flow of cool groundwater into the heated treatment zone (not a true hot floor). Additionally, the BFS would have to be uniformly heated in order to effectively mitigate the downward mobilization risk posed by steam injection, but given the large size of the DNAPL-impacted area, there is an increased potential for development of cold spots. Therefore, implementation of a hot floor in the BFS may not be a reliable method for preventing downward migration during a steam injection remedy. The hot floor at the Montrose Site would not be a clay, like most other hot floor applications, but instead would be a "thermal barrier", which has to prevent DNAPL from migrating into the BFS, a highly transmissive aquifer. Criteria for implementation of a hot floor at the Montrose Site would include:

- It must be heated in advance of the UBA so that downward migrating DNAPL is thermally treated;
- It must be uniformly heated despite any heterogeneities of the soil or any groundwater influx from the surrounding formation;
- It must have an effective extraction system to recover displaced groundwater and the cold-water equivalent of the injected steam;
- It must be operated at near 100% of the available time so that it does not cool during periods of downtime;
- It must have an effective monitoring system to verify that target temperatures are reached and maintained.

At the Del Amo Superfund Site located less than 0.25 miles east of the Montrose Site, thermal remediation technologies were also evaluated for treatment of a light non-aqueous phase liquid (LNAPL). A Soil and NAPL FS was issued for that site in July, 2008 (URS, 2008). According to the FS, "*the low permeability and heterogeneous character of soils at the former plant site would interfere with the uniform transmission of the steam through the subsurface*". Consequently, the FS concluded that "*the source areas at this site are generally not well suited for application of this technology compared to other aggressive thermal technologies considered*". The LNAPL-impacted aquitard at the Del Amo Site is similar to the DNAPL-impacted UBA at the Montrose Site in at least one source area located on the west side of the Del Amo Site. The aquitard, also identified as the Upper Bellflower (UBF), was characterized as being highly layered with interbedded sands and silts. The aquitard at the Del Amo Site becomes less layered to the east, and the layers are generally more continuous at the Del Amo Site. However, the two aquitard zones have a significant number of similarities. Although URS indicated that steam injection was retained at EPA's request, it was not assembled into a formal remedial alternative.

There are no comparable sites to the Montrose Site where steam injection has been implemented. Considering the thickness of the treatment interval, the unusual nature of the Montrose DNAPL, and the heterogeneous nature of the saturated UBA, steam injection at the Montrose Site could be the most complicated steam remediation project, if undertaken. ***Ranking: Potentially Effective (but uncertain).***

Implementability. This thermal remediation process option would be difficult to implement. A significant amount of infrastructure would be required to generate and deliver steam throughout the DNAPL impacted zone. A large number of wells, steam injection and multiphase extraction, would be required to treat the entire DNAPL-impacted area and would generate a significant amount of waste requiring management and disposal. This process option would additionally require implementation of SVE to recover VOCs for ex-situ treatment. This process option additionally requires extraction and ex-situ treatment of total fluids including groundwater/condensed steam and DNAPL. Under this process option, implementation of a hot floor in the underlying BFS may additionally be required to reduce the risks associated with downward migration of DNAPL and steam condensate.

This process option would require highly skilled operators and a high level of maintenance, including boiler maintenance and management of boiler brine waste. Steam injection is an energy-intensive remedial technology, and the amount of energy required to heat the entire DNAPL-impacted area would be significant. The resulting carbon footprint for a full-scale steam injection remedy would be similarly large and not in accordance with EPA green remediation initiatives. There is additionally an increased potential for heated vapors or contaminated steam to be accidentally released to atmosphere as a fugitive emission. For example, at the SCE Visalia site and despite significant participation by EPA and thermal remediation experts, one well suffered a catastrophic failure due to incompatibility of the bentonite annular seal materials with the elevated temperatures of the full-scale steam remedy, releasing steam, hot water, and sediment to atmosphere.

Another important factor limiting the implementability of this process option is a lack of steam vendors. Only two thermal remediation vendors, TerraTherm and Praxis Environmental, continue to pursue steam injection for site remediation. Previously, SteamTech and McMillan-McGee offered and actively marketed steam injection as a remedial technology. However, SteamTech has since been dissolved, and McMillan-McGee no longer pursues steam injection as a commercial technology, although it still has a license for steam injection. Praxis Environmental is an exceptionally small, independent firm (one person) with insufficient resources to implement a project of this size. TerraTherm is the only thermal remediation vendor still pursuing steam injection as a commercial technology with the potential to implement a project of this size, although the majority of thermal remediation projects implemented by TerraTherm are substantially smaller in size than the Montrose Site. A lack of adequate commercial steam injection vendors limits the implementability of this process option. ***Ranking: Difficult to Implement.***

Cost. The relative cost for this thermal technology process option is very high. Under this thermal process option, high costs are incurred for steam injection and multiphase extraction well installation, waste disposal, and energy consumption (primarily natural gas for steam boiler). Although pressure cycling can be implemented to reduce the energy demand of a steam injection remedy, there are also a number of potential inefficiencies that could increase the energy demand. This process option requires both soil vapor and groundwater extraction, resulting in high ex-situ treatment costs. If a hot floor is implemented as a component of the steam injection remedy, costs for this process option are further increased. Moreover, the paucity of steam vendors may add to the costs due to a lack of competition. Steam injection costs would be further increased if more than 2 to 3 pore volumes of steam flushing are required by the thermal remedy, as suggested by the experience at the SCE Visalia Site and Savannah River Site. ***Ranking: Very High.***

Retain for Assembly of Remedial Alternatives? The potential effectiveness of this process option is highly uncertain given the Site conditions and unique nature of the Montrose DNAPL. Additionally, the potential effectiveness of this thermal technology has not been demonstrated through field pilot testing, and 2-dimensional bench-testing raises doubts about the potential effectiveness of this technology. Additionally, there is downward mobilization risks associated with this thermal technology, and therefore, implementation of hot floor within the underlying BFS would be required as a component of steam injection. Despite its technical uncertainties, implementability challenges, and high cost, EPA has indicated a desire to evaluate candidate thermal remediation technologies in this FS. Although Montrose does not agree, steam injection is retained for further evaluation as requested by EPA and based on its potential effectiveness in reducing DNAPL mass and mobility by vaporizing the MCB component and flushing the Montrose DNAPL. ***Retained? Yes.***

4.7 EX-SITU GROUNDWATER TREATMENT

Process Description. Ex-situ groundwater treatment technologies for the Site have been extensively evaluated. The Groundwater ROD identified liquid-phase granular activated carbon (LGAC) as the primary treatment technology for MCB and other VOCs in groundwater, and the performance of LGAC in treating these contaminants has previously been tested on three occasions (McLaren-Hart, 1997; H+A, 2005; Earth Tech, 2008i). The Groundwater ROD additionally identified advance oxidation as a GRA for treatment of pCBSA in groundwater, and the performance of two advanced oxidation technologies (Trojan UV-PHOX™ and APT HiPOx™) in treating this contaminant have previously been tested on two occasions (Earth Tech, 2004b and 2008h, respectively). Trojan UV-PHOX™ is a technology that uses ultraviolet light (UV) and hydrogen peroxide to catalyze formation of hydroxyl radicals which oxidize dissolved constituents in groundwater. APT HiPOx™ is a technology that uses ozone and hydrogen peroxide to form hydroxyl radicals and oxidize dissolved constituents in groundwater.

The full-scale treatment system for the groundwater remedy is currently in design but is expected to be composed of LGAC and one of the two advanced oxidation technologies. For the purpose of this FS, groundwater extracted by the DNAPL remedial alternatives is assumed to be treated using a combination of LGAC and advanced oxidation techniques. Additionally, it is assumed that a separate pre-treatment plant (separate from the groundwater remedy treatment plant) would be used to treat groundwater extracted as part of a DNAPL remedy. Dissolved contaminant concentrations within the DNAPL-impacted zone are substantially higher than those to be addressed by the groundwater remedy. Therefore, to simplify design considerations, a separate groundwater pre-treatment system dedicated to the DNAPL remedy is assumed for this FS. In addition to dissolved contaminants, groundwater would be treated using physical separation methods to remove DNAPL and filter out suspended solids. The ex-situ groundwater treatment system would be connected to the DNAPL wellfield via an aboveground piping network.

Effectiveness. Ex-situ treatment of UBA groundwater using a combination of LGAC and advanced oxidation will be effective. The effectiveness of treating MCB in groundwater using LGAC was previously demonstrated during bench tests conducted in 2005 (H+A, 2005) and 2008 (Earth Tech, 2008i). MCB concentrations in groundwater up to 33,000 ug/L were treated during these tests, and LGAC was found to be highly effective in removing MCB from groundwater with up to 33% adsorption on a weight basis. Although dissolved MCB concentrations within the DNAPL-impacted zone can exceed 100,000 ug/L, LGAC will be no less effective in treating MCB (although more LGAC may be consumed).

The effectiveness of treating pCBSA in groundwater using either HiPOx™ or Trojan UV-PHOX™ was demonstrated during field and bench tests conducted in 2003 (Earth Tech, 2004b) and 2008 (Earth Tech, 2008h) , respectively. pCBSA concentrations in groundwater up to 81,000 ug/L were treated during these tests, and both advanced oxidation process options were found to be effective in meeting target remediation goals as low as 100 ug/L. However, discoloration of the groundwater was observed during UV-oxidation testing, inhibiting UV transmittance and formation of hydroxyl radicals. As a result, Trojan UV-PHOX™ may not be as effective on a full-scale basis as HiPOx™, which does not rely on groundwater clarity or UV transmittance. ***Rank: Effective.***

Implementability. There are no technical or administrative aspects that would limit the implementability of this ex-situ groundwater treatment technology, which is also expected to be implemented as part of the groundwater remedy. ***Rank: Implementable.***

Cost. The relative cost of this process option is high due to the high dissolved concentrations present within the DNAPL-impacted zone, although it is the only ex-situ treatment technology considered for groundwater. ***Rank: High.***

Retain for Assembly of Remedial Alternatives? As the only ex-situ groundwater treatment technology evaluated in the FS, this process option is automatically retained for assembly in remedial alternatives. ***Retained? Yes.***

4.8 EX-SITU VAPOR TREATMENT

Ex-situ treatment of extracted soil vapors will be necessary if SVE is included as a component of an assembled remedial alternative. Three ex-situ vapor treatment process options are potentially applicable to the Site, including thermal oxidation with acid gas scrubbing, steam-regenerable carbon or resin, and disposable carbon or resin. Each of the three vapor treatment process options are evaluated against the three preliminary screening criteria in the following sections.

4.8.1 THERMAL OXIDATION/ACID GAS SCRUBBING

Process Description. Thermal oxidation is a destructive technology for treatment of VOCs in off-gas vapors. VOC-impacted soil vapors from an SVE remedial alternative would be directed to a combustion chamber for oxidation at temperatures exceeding 1,500°F. The products of combustion would include carbon dioxide, water vapor, and acid gas, and the effluent from the thermal oxidizer would then be further treated for removal of the acid gas via a water-cooled quench and wet scrubber.

Thermal oxidation systems are either direct-fired or flameless. For direct-fired systems, combustion of VOC-impacted soil vapors is achieved using a propane or natural gas fired flame. Flameless thermal oxidizers (FTOs) achieve combustion using either a heated porous ceramic tube burner or ceramic packed-bed reactor. Both thermal oxidation systems require the addition of either propane or natural gas as supplemental fuel for combustion, particularly when the energy or BTU-content of the soil vapors is low. Recuperative and regenerative thermal oxidation systems have the ability to recover heat and use less supplemental fuel.

Effectiveness. Thermal oxidation is an effective and reliable method for treating chlorinated hydrocarbon vapors and is widely used throughout the environmental industry. Direct-flame thermal oxidizers typically achieve VOC destruction efficiencies of approximately 99%, while FTOs offer destruction efficiencies up to 99.99%. Because of the higher efficiency, FTOs are capable of treating higher influent contaminant concentrations such as would be experienced during a DNAPL remedy. Wet scrubbers are also widely used for neutralization of acid gases. Thermal oxidizers are effective in meeting air quality emission standards, particularly FTOs which offer low emissions of nitrogen and sulfur oxides. ***Rank: Effective.***

Implementability. Thermal oxidation of soil vapors is implementable. Pre-engineered systems for thermal oxidation of chlorinated hydrocarbons are available from a variety of manufacturers, although FTOs are not as widely available as direct-fired thermal oxidizer systems. An FTO was recently used to treat soil vapors at the Pemaco Superfund Site in Maywood, California as a component of a thermal remediation and SVE alternative. It is noted that thermal oxidation is a candidate ex-situ vapor treatment technology evaluated in the Soil and NAPL FS for the Del Amo Superfund Site (URS, 2008). Thermal oxidizers meet the technical and administrative air quality standards established by the South Coast AQMD. A primary advantage of this process option is that the vapor-phase contaminants are destroyed, not captured, and do not require subsequent waste management and disposal. However, because thermal oxidation is a combustion process, analysis of the system effluent for products of incomplete combustions is often required. Additionally, thermal oxidizers with acid gas scrubbers are complex systems that require skilled operators and a relatively high level of maintenance. Acid gas scrubbers additionally generate a constant wastewater stream that requires management and disposal. Additionally, in Southern California, it is necessary to soften the city water for use as cooling water for thermal oxidizing quench and scrubbing. ***Rank: Implementable.***

Cost. The relative cost for this soil vapor treatment process option is moderate to high, depending on the type of thermal oxidization system selected. Direct-fired thermal oxidizers are lower in cost and recuperative heat methods can be used to reduce the cost of make-up fuel. FTOs are higher in cost and are expensive to maintain. For sites with chlorinated VOCs (which have a low energy content), the cost of supplemental fuel (propane or natural gas) is high. ***Rank: Medium to High.***

Retain for Assembly of Remedial Alternatives? This process option is retained because it is an effective method for destroying MCB and other VOCs in soil vapors extracted using an SVE remedial technology. ***Retained? Yes.***

4.8.2 REGENERABLE CARBON/RESIN ADSORPTION

Process Description. In this process, the extracted soil vapors are treated using granular activated carbon or resin. Soil vapors are passed through a packed bed or vessel containing activated carbon or resin and are removed from the vapor stream by adsorption. The vapor treatment process is the same as with disposable carbon, but under this process option, spent carbon/resin beds are regenerated on-Site using low pressure steam. The steam heats the carbon/resin beds up to approximately 300°F, thereby desorbing and volatilizing the contaminants. The steam and contaminated vapors are purged to a liquid-cooled condenser and subsequent decanter for separation of the liquid-phase contaminants (DNAPL) from steam condensate. The recovered liquid-phase contaminants are then transported off-Site for recycling or disposal. The condensed steam contains dissolved-phase contaminants and is either disposed directly or treated off-Site, typically via disposable LGAC, prior to disposal. The steam regenerated carbon/resin is air-cooled and then placed back into service. Typically, these systems are designed with paired lead vessels, one active and one inactive, to eliminate the need for interruption in soil vapor treatment during carbon/resin regeneration. The active lead vessel is switched once it is ready for steam regeneration.

Effectiveness. This process option is effective in treating soil vapors from the Site. Disposable carbon, which treats soil vapors in an identical manner, was used during the SVE pilot test conducted at the Site in 2003 (Earth Tech, 2004a). Approximately 4,700 pounds of vapor-phase contaminants were treated during that test in compliance with South Coast AQMD emission criteria. Multiple carbon vessels were connected in series in order to effectively treat the elevated VOC concentrations in soil gas, up to approximately 14,000 ppmv as total gaseous non-methane organics (the majority of which was MCB and chloroform). A high rate of VOC mass adsorption, approximately 25% by weight, was observed during that field pilot test. A steam regenerable carbon/resin system is expected to be equally effective in treating VOCs in soil vapor, although multiple vessels may need to be connected in series in order to achieve a high enough removal efficiency to comply with emission standards. Steam has been widely and successfully used to regenerate or reactivate carbon for reuse. The efficiency of the reactivation process diminishes over time, and after a sufficient number of reactivation cycles, the regenerable carbon is replaced. ***Rank: Effective.***

Implementability. Ex-situ treatment of soil vapors using steam-regenerable carbon/resin is implementable. Pre-engineered regenerable carbon/resin systems are available from a variety of manufacturers, although resin is not as widely used as carbon. These vapor treatment systems meet the technical and administrative air quality standards established by the South Coast AQMD. Steam-regenerable carbon/resin systems require skilled operators and a relatively high level of maintenance. Challenges with implementing this option include corrosion of the carbon/resin support screens, effective gravity separation of the condensed contaminants and steam, and management of the relatively large volumes of contaminated steam condensate and recovered solvent. ***Rank: Implementable.***

Cost. The relative cost for this soil vapor treatment process option is moderate to high, depending on the volume of waste generated for off-Site disposal. The primary disadvantage of this process option is the high cost associated with managing and disposing of the waste streams. Unlike thermal oxidation, VOCs are captured and require off-Site disposal as a liquid waste. Although the carbon used for this process option requires only infrequent replacement, the steam condensate becomes contaminated via the regeneration process and requires off-Site disposal or treatment (or both). ***Rank: Medium to High.***

Retain for Assembly of Remedial Alternatives? This process option is retained because it is an effective method for removing MCB and other VOCs from soil vapors extracted using an SVE remedial technology. Additionally, this vapor treatment process option is particularly applicable for remedial alternatives involving steam injection. ***Retained? Yes.***

4.8.3 DISPOSABLE CARBON/RESIN ADSORPTION

Process Description. In this process, the extracted soil vapors are treated using disposal carbon or resin adsorption beds. Soil vapors are passed through a packed bed/vessel containing activated carbon or resin and are removed from the vapor stream by adsorption. Multiple vessels are connected in series as needed to meet emission goals. Once the carbon/resin in the lead vessel becomes spent, it is replaced with fresh carbon or resin and repositioned to the end of the treatment train. Spent carbon/resin is transported off-Site for reactivation or disposal. Virgin or reactivated carbon can be used for this process option, or alternately a polymeric resin such as the Ambersorb® product line.

Effectiveness. This process option is effective in treating MCB and other VOCs in soil vapors as demonstrated during the 2003 SVE field pilot test (Earth Tech, 2004a). As described in Section 4.8.2, multiple disposable carbon vessels connected in series were effective in treating approximately 4,700 pounds of vapor-phase contaminants during the field pilot testing and in compliance with South Coast AQMD emission limits. A high rate of VOC mass adsorption, approximately 25% by weight, was observed during that pilot test. Resin would be expected to exhibit a similarly high MCB mass adsorption efficiency. It is noted that disposable carbon adsorption was implemented as the ex-situ vapor control technology for the former waste pits at the Del Amo Superfund Site located immediately east of the Montrose Site. ***Rank: Effective.***

Implementability. Ex-situ treatment of soil vapors using disposable carbon/resin is implementable. This process option requires only a low level of maintenance and does not require highly skilled operators. This vapor treatment process option meets the technical and administrative air quality standards established by the South Coast AQMD. The primary disadvantage of this vapor treatment process option is the high volume of spent carbon/resin to manage and dispose. High carbon/resin usage rates can increase the difficulty of implementing this process option, particularly in coordinating carbon/resin replacement. ***Rank: Implementable.***

Cost. The relative cost for this vapor treatment process option is moderate to high, depending on the volume of carbon/resin consumed during the remedy. As the volume of disposable carbon/resin consumed increases, the cost effectiveness of this vapor treatment process option decreases. For an SVE alternative targeting the PVS and unsaturated UBA only, the relative cost of this process option would be moderate and potentially comparable with the other vapor treatment process options. However, for a combined thermal remediation/SVE remedial alternative for example, targeting both the unsaturated and saturated zones, the relative cost of this process option would be very high and likely higher than the other vapor treatment process options. ***Rank: Medium to High.***

Retain for Assembly of Remedial Alternatives? This process option is retained because it is an effective method for removing MCB and other VOCs from soil vapors extracted using an SVE remedial technology. This ex-situ soil vapor treatment process option may be cost effective in combination with SVE in the unsaturated zone and will be considered for some alternatives. However, the volume of disposable carbon/resin required to treat vapor-phase contaminants removed by a thermal remediation technology implemented in the saturated UBA would be excessive and cost prohibitive. For remedial alternatives where thermal remediation of the saturated UBA is a component, either steam-regenerable carbon/resin or thermal oxidation/acid gas scrubbing will be considered for ex-situ soil vapor treatment. ***Retained? Yes.***

4.9 DISPOSAL

This section evaluates three different process options for disposal (recycling) of groundwater extracted during a DNAPL remedial action. The various DNAPL remedial technologies considered in this FS are expected to generate up to approximately 250 gpm of groundwater. All process options evaluated for groundwater disposal involve re-injection, either into the saturated UBA or alternately into the BFS and Gage Aquifers. Re-injection of both treated and untreated groundwater into the UBA is evaluated.

Disposal process options evaluate (a) whether groundwater is treated prior to re-injection, and (b) whether groundwater is re-injected on-Property into the UBA or off-Property into the BFS and Gage Aquifers. For disposal process options involving groundwater treatment, the technologies identified in Section 4.7 are assumed. Disposal process options do not evaluate different ex-situ treatment technologies. Since two of the three disposal process options include ex-situ groundwater treatment, the cost of ex-situ treatment is included for the those options in order to provide a comparative evaluation with the option that excludes ex-situ treatment.

Re-injection preserves the groundwater resource and enhances hydraulic gradients. Disposal of extracted groundwater to the industrial sewer or municipal storm drain do not preserve the groundwater resource or enhance hydraulic gradients and are not considered by this FS. Additionally, obtaining an industrial sewer discharge permit for a new source can be problematic due to limited sewer capacities, and there is no cost benefit to discharging treated groundwater to the municipal storm drain. Further, no storm catch basin exists along the western side of Normandie Avenue. One process option is also evaluated for disposal of recovered DNAPL.

4.9.1 INJECTION OF TREATED WATER AS PART OF GROUNDWATER REMEDY

Process Description. Under this disposal process option, groundwater extracted as part of a DNAPL remedy would be treated for dissolved contaminants as discussed in Section 4.7 and then transferred to the groundwater remedy treatment system for re-injection into the off-Property BFS and Gage Aquifer injection wells that are part of the groundwater remedy. Because the dissolved concentrations of MCB and pCBSA in the UBA groundwater will be substantially higher than the water treated as part of the groundwater remedy, a separate treatment train dedicated to the DNAPL remedy was assumed. This process option does not require installation of any re-injection wells.

Effectiveness. This disposal process option is effective to address extracted groundwater. The location of re-injected groundwater under this option particularly impacts thermal remedial technologies because re-injection of treated groundwater into the DNAPL-impacted UBA could serve to cool the subsurface and reduce the effectiveness of a thermal remedial alternative. Pilot testing conducted as part of the groundwater remedy indicates that injection of water into the BFS and Gage Aquifer can be effectively implemented. However, because treated groundwater is not re-injected into the saturated UBA, it does not serve to enhance the hydraulic gradient or increase flushing associated with a hydraulic displacement remedial alternative. Recycling extracted groundwater is an effective pollution prevention strategy for reducing the volume of wastewater requiring disposal to publicly owned treatment works. ***Rank: Effective.***

Implementability. This disposal process option is implementable and would need to meet the administrative requirements for groundwater re-injection specified in the Groundwater ROD. However, the increased groundwater volume requiring re-injection into the BFS and Gage Aquifers must be considered during groundwater Remedial Design (RD). The increased re-injection flow rate may affect wellfield design, equipment and piping sizing, and in-situ hydraulic gradients, particularly for DNAPL process options with up to 200 to 250 gpm of treated groundwater (approximately 30% to 35% of the planned re-injection rate for the groundwater remedy). ***Rank: Implementable.***

Cost. The relative cost for this process option is high since dissolved-phase concentrations of both MCB and pCBSA will be elevated and a separate treatment train would have to be implemented to address treatment of these contaminants. ***Rank: High.***

Retain for Assembly of Remedial Alternatives? This disposal process option for groundwater is retained for assembly into remedial alternatives. Although alternate groundwater disposal process options may be more effective for hydraulic displacement, this process option would be effective for DNAPL thermal remediation technologies. ***Retained? Yes.***

4.9.2 INJECTION OF TREATED WATER AS PART OF HYDRAULIC DISPLACEMENT

Process Description. Under this disposal process option, groundwater extracted as part of a DNAPL remedy would be treated for dissolved contaminants and then re-injected back into the saturated UBA for purposes of enhancing hydraulic gradients and DNAPL flushing. This process option is specifically evaluated for purposes of supporting a hydraulic displacement remedy. Under this option, a separate treatment train dedicated to the DNAPL remedy is assumed to treat elevated dissolved concentrations of MCB and pCBSA to the re-injection standards established in the Groundwater ROD, which is identical to the option for re-injection of treated groundwater as part of a groundwater remedy. A series of injection wells spaced throughout the DNAPL-impacted zone and an associated piping network would be required for this process option.

Effectiveness. This groundwater disposal process option is technically effective and would substantially enhance gradients under a hydraulic displacement alternative, as compared to the process option set forth in 4.9.1 above. Recycling extracted groundwater is an effective pollution prevention strategy for reducing the volume of wastewater requiring disposal to publicly owned treatment works. Groundwater was re-injected into the saturated UBA during the 2004/2005 DNAPL extraction pilot test (H+A, 2007c). The specific capacities of two UBA injection wells, UBI-1 and UBI-2, were measured at 2.1 and 4.8 gpm per foot respectively. The differences in specific capacities were related to differences in the thickness and permeability of the saturated sand layers screened by the injection wells. Although the two injection wells were successful in disposing of the groundwater back to the UBA, the specific capacity of injection well UBI-1 had decreased to approximately 0.9 gpm per foot by the end of the pilot test (a 57% reduction in the re-injection capacity). However, fouling of injection wells is not uncommon and, often times, routine re-development can regain much of the lost specific capacity. For this process option to be effective, groundwater must be delivered back to the layers in which DNAPL occurs. Additionally, dissolved contaminants are removed from groundwater prior to re-injection, marginally increasing the rate of contaminant mass removal. ***Rank: Effective.***

Implementability. This groundwater disposal process option is implementable. However, injection well fouling could increase the difficulty of implementing this process option. ***Rank: Implementable.***

Cost. The relative cost for this groundwater disposal process option is high since dissolved concentrations of both MCB and pCBSA will be elevated and will require a separate treatment train. Treatment of dissolved contaminants and an injection well network are both required for this process option. A relatively high number of injection wells may be required to dispose of the groundwater, and fouling of the injection wells will increase the cost of this process option. ***Rank: High.***

Retain for Assembly of Remedial Alternatives? This groundwater disposal process option is not retained for assembly into remedial alternatives. Ex-situ treatment of groundwater is not required to implement hydraulic displacement, and the marginal increase in the rate of contaminant mass removal does not justify the high relative cost. ***Retained? No.***

4.9.3 INJECTION OF UNTREATED WATER AS PART OF HYDRAULIC DISPLACEMENT

Process Description. Under this disposal process option, untreated groundwater extracted as part of a DNAPL remedy would be re-injected back into the saturated UBA for purposes of enhancing hydraulic gradients and DNAPL flushing. This process option is specifically evaluated for purposes of supporting a hydraulic displacement remedy. Unlike the two process options for reinjection of treated groundwater, the dissolved concentrations of MCB and pCBSA would not be treated prior to re-injection. Groundwater would be separated from DNAPL and filtered prior to re-injection to remove suspended solids and minimize fouling, but groundwater would otherwise not be treated to remove dissolved contaminants. This approach was utilized during the most recent DNAPL extraction testing conducted at the Site, since the impacted groundwater was injected into the UBA within the footprint of the TI Waiver Zone. Injected groundwater within that zone would be contained indefinitely through groundwater containment systems and eventually treated through the groundwater remedy. A series of injection wells spaced throughout the DNAPL-impacted zone and an associated piping network would be required for this process option.

Effectiveness. Although no dissolved MCB or pCBSA will be removed from the groundwater, this process option is equally effective in terms of enhancing hydraulic gradients and DNAPL flushing. This process option was implemented during the 2004/2005 DNAPL extraction pilot test and found to be effective in delivering groundwater back to the UBA. Prior to injection, extracted groundwater was separated from DNAPL and filtered to remove suspended solids to minimize the potential for plugging which could result in loss of injection well capacity. Fouling of the UBA injection wells during a DNAPL remedy would make this groundwater disposal process option less effective. However, fouling of injection wells is not uncommon and, often times, routine re-development can regain much of the lost specific capacity. Additionally, for this process option to be effective, groundwater must be delivered back to the layers in which DNAPL occurs.

The impact of injecting untreated groundwater from extraction wells was assessed during the 2004/2005 DNAPL extraction pilot test (H+A, 2007c). Analytical data for the groundwater samples collected prior to, during, and following the DNAPL extraction testing program revealed that dissolved concentrations were within the typical range of values for both the upgradient monitoring well, MW-8, located approximately 400 feet northwest of the Property, and the downgradient monitoring well, MW-14, located approximately 800 feet south-southeast of the Property. Re-injection of untreated groundwater during the 2004/2005 DNAPL extraction test did not adversely impact groundwater quality around the CPA within the TI Waiver Zone footprint. ***Rank: Effective.***

Implementability. This groundwater disposal process option is technically implementable. However, injection well fouling could increase the difficulty of implementing this process option. Additionally, the dissolved contaminant in the groundwater will exceed the re-injection standards established in the Groundwater ROD. In order for this process option to be administratively implementable, the re-injection standards would need to be waived, which was done for the 2004/2005 extraction testing. Based on the 2004/2005 pilot test, re-injection of untreated groundwater is not expected to adversely impact groundwater quality within the saturated UBA within the footprint of the TI Waiver Zone. Furthermore, hydraulic containment will serve to control any potential contaminant migration in the long-term. ***Rank: Implementable.***

Cost. The relative cost for this groundwater disposal process option is low because treatment of dissolved contaminants is not required. However, a relatively high number of injection wells may be required to dispose of the groundwater given the low hydraulic conductivities of the UBA, and fouling of the injection wells likely will increase the cost of this process option. ***Rank: Low.***

Retain for Assembly of Remedial Alternatives? This groundwater disposal process option is retained for assembly into remedial alternatives. ***Retained? Yes.***

4.9.4 OFF-SITE INCINERATION OF DNAPL

DNAPL extracted as part of a remedial action would require off-Site disposal as a hazardous waste. However, there are limited options for disposal of the Montrose DNAPL, which is composed of approximately 50% DDT. Therefore, the only disposal process option considered for DNAPL is off-Site incineration.

Process Description. Recovered DNAPL would be drummed, manifested as a hazardous waste, and transported off-Site for incineration within 90 days of generation.

Effectiveness. This disposal process option is effective. ***Rank: Effective.***

Implementability. This disposal process option has historically been used to manage DNAPL waste generated at the Site and is readily implementable. Off-Site disposal of DNAPL waste within 90 days of generation eliminates administrative aspects that would otherwise limit the implementability of this process option. ***Rank: Implementable.***

Cost. The relative cost for this disposal process option is high, although it is the only process option considered for DNAPL waste. ***Rank: High.***

Retain for Assembly of Remedial Alternatives? As the only disposal process option considered for DNAPL waste, off-Site incineration is retained for assembly into remedial alternatives. ***Retained? Yes.***

4.10 SUMMARY OF REMEDIAL TECHNOLOGY/PROCESS OPTIONS RETAINED FOR ASSEMBLY INTO REMEDIAL ALTERNATIVES

This section summarizes the GRA remedial technologies and process options retained, following the preliminary screening, for assembly into remedial alternatives.

Remedial Technologies and Process Options Retained For Assembly into RAs

General Response Action	Remedial Technology/Process Option
No Action	None
Institutional Controls	Deed Restrictions
	Access Restrictions
	Limit Groundwater Use
	DNAPL and Groundwater Monitoring
Containment	Hydraulic Extraction
Extraction Technologies	Soil Vapor Extraction (unsaturated zone)
	Hydraulic Displacement (with water injection)
In-Situ Thermal Technologies	Electrical Resistance Heating
	Steam Injection
Ex-Situ Groundwater Treatment	Liquid-Phase Granular Activated Carbon (for MCB) and Advanced Oxidation (for pCBSA)
Ex-Situ Vapor Treatment	Thermal Oxidation with Acid Gas Scrubbing
	Regenerable Carbon/Resin Adsorption
	Disposable Carbon/Resin Adsorption
Disposal	Injection of Treated Water as part of Groundwater Remedy
	Injection of Untreated Water as part of Hydraulic Displacement
	Off-Site Incineration of DNAPL

The above remedial technologies and process options will be assembled into candidate remedial alternatives in Section 5.0. The candidate remedial alternatives will be described and further evaluated.

TABLES

TABLE 4.1
Preliminary Screening of DNAPL Remedial Technologies and Process Options
Draft DNAPL FS
Montrose Superfund Site

General Response Action	Remedial Technology/ Process Option	Description	Technical Effectiveness	Implementability	Relative Cost	Retain for Assembly into Remedial Alternatives (Yes/No)
No Action	None	No further action will be taken at the Site other than actions implemented as part of the soil and/or groundwater remedies	• Moderately effective • Actions to be implemented as part of soil and groundwater remedies will protect human health • Groundwater containment activities will reduce DNAPL mass in the long-term	• Implementable	None	Yes
Institutional Controls	Deed Restrictions	Restrict future use of the Site or activities conducted at the Site through a Land Use Covenant	• Moderately effective • Will restrict human exposure to Site contaminants	• Implementable • Deed restriction in off-Property areas would require consent of the land owners	Low	Yes
	Access Restrictions	Restrict access to the Site through fencing and warning signs	• Moderately effective • Will restrict human exposure to Site contaminants	• Implementable • Already in place at Site	Low	Yes
	Limit Groundwater Use	Limit the ways in which groundwater may be used and prohibit extraction of groundwater for beneficial purposes	• Moderately effective • Will limit human exposure to contaminants in groundwater	• Implementable • Part of groundwater remedy	Low	Yes
	DNAPL and Groundwater Monitoring	Monitor for migration of DNAPL and dissolved-phase MCB to verify hydraulic containment	• Moderately effective • Will verify effectiveness of hydraulic containment program	• Implementable • Part of groundwater remedy	Low	Yes
Containment	Hydraulic Extraction	Contain dissolved MCB plumes in UBA, BFS, and Gage through long-term hydraulic extraction and in compliance with TI Waiver Zone	• Effective • Dissolved-phase contaminants will be contained within TI Waiver Zone • DNAPL mass will be reduced in the long-term • Reliable process option widely implemented at DNAPL sites	• Implementable • Part of groundwater remedy	None	Yes

TABLE 4.1 (continued)
Preliminary Screening of DNAPL Remedial Technologies and Process Options

General Response Action	Remedial Technology/ Process Option	Description	Technical Effectiveness	Implementability	Relative Cost	Retain for Assembly into Remedial Alternatives (Yes/No)
Extraction Technologies	Soil Vapor Extraction (SVE)	Soil gas containing vapor-phase contaminants is extracted under vacuum for ex-situ treatment	• Highly effective for removal of VOCs from permeable unsaturated soils • Was field pilot tested in 2003; high VOC mass removal rate observed from PVS and unsaturated UBA • MCB component of DNAPL will be volatilized by SVE; reduces DNAPL mass and mobility • Will prevent VOC migration in soil gas in unsaturated zone • Not effective for removal of DDT • Will be significantly less effective in low permeability PD soils	• Implementable	Medium	Yes
	Passive DNAPL Extraction	DNAPL passively accumulates in wells and is removed for off-Site disposal	• Minimally effective • Only mobile DNAPL that intercepts the wells is available to be recovered • Less than 300 gallons of DNAPL recovered since 1988 from a small number of wells	• Implementable • Passive DNAPL recovery has been on-going since 1988	Low	No
	Hydraulic Displacement	Hydraulic gradients are created by simultaneous groundwater extraction and re-injection to displace DNAPL towards recovery wells for direct extraction and off-Site disposal	• Effective in recovering mobile DNAPL • Field pilot tested three times; DNAPL recovery rates up to 1,000 times faster than passive recovery rates • Reduces DNAPL mass and mobility, is a depletion technology • Higher DNAPL recovery rates are expected if water is re-injected to increase hydraulic gradients • Will not be effective for residual DNAPL occurring in low saturations (already immobile) • Higher density of wells may be required to effectively displace and recover DNAPL in the heterogeneous UBA	• Implementable • Routine maintenance required to prevent precipitate fouling of the extraction equipment	Low to Medium	Yes

TABLE 4.1 (continued)
Preliminary Screening of DNAPL Remedial Technologies and Process Options

General Response Action	Remedial Technology/ Process Option	Description	Technical Effectiveness	Implementability	Relative Cost	Retain for Assembly into Remedial Alternatives (Yes/No)
Extraction Technologies (cont'd)	Surfactant-Enhanced Aquifer Remediation (SEAR)	Surfactants are injected into the saturated zone to mobilize DNAPL for recovery by hydraulic displacement; the surfactants lower the interfacial tension between water and DNAPL	• Potentially effective (but highly uncertain); has not been bench or field pilot tested • Technology is infrequently applied; no sites comparable to Montrose • Higher density of wells may be required to effectively deliver surfactants throughout heterogeneous UBA • Increased risk of downward mobilization; no underlying confining layer to prevent impacts to BFS	• Difficult to implement • Specialized chemicals and contractors are required • Regulatory approval is required for surfactant injection • Separation of DNAPL at surface can be problematic	High	No
	Cosolvent Injection	Cosolvents are injected into the saturated zone to mobilize DNAPL for recovery by hydraulic displacement; cosolvents are miscible in water and DNAPL and serve to decrease interfacial tension and increase dissolution	• Potentially effective (but highly uncertain); has not been bench or field pilot tested • Technology is infrequently applied; no sites comparable to Montrose • Higher density of wells may be required to effectively deliver cosolvents throughout heterogeneous UBA • Increased risk of uncontrolled mobilization; DNAPL mobility is increased, not reduced; no underlying confining layer to prevent impacts to BFS • DDT is likely to precipitate and potentially foul permeable soils and wells	• Difficult to implement • Specialized chemicals and contractors are required • Regulatory approval is required for cosolvent injection • Separation of DNAPL at surface can be problematic	High	No

TABLE 4.1 (continued)
Preliminary Screening of DNAPL Remedial Technologies and Process Options

General Response Action	Remedial Technology/ Process Option	Description	Technical Effectiveness	Implementability	Relative Cost	Retain for Assembly into Remedial Alternatives (Yes/No)
Extraction Technologies (cont'd)	Polymer Flooding	Polymers are injected into the saturated zone to mobilize DNAPL for recovery by hydraulic displacement; polymers increase the viscosity of the soil washing fluid (i.e. groundwater) increasing the effectiveness of DNAPL displacement	• Potentially effective (but highly uncertain); has not been bench or field pilot tested • Technology is infrequently applied; no sites comparable to Montrose • Higher density of wells may be required to effectively deliver polymers throughout heterogeneous UBA • Increased risk of uncontrolled mobilization; DNAPL mobility is increased, not reduced; no underlying confining layer to prevent impacts to BFS	• Difficult to implement • Injection of viscous polymer solutions into saturated UBA may be problematic, resulting in frequent well fouling • Specialized chemicals and contractors are required • Regulatory approval is required for polymer injection	High	No
	Alcohol Flooding	High concentration alcohols are injected into the saturated zone to mobilize DNAPL for recovery by hydraulic displacement; the alcohols are miscible with DNAPL, reducing their density and interfacial tension	• Potentially effective (but highly uncertain); has not been bench or field pilot tested • Technology is infrequently applied; no sites comparable to Montrose • Higher density of wells may be required to effectively deliver alcohol throughout heterogeneous UBA • Increased risk of uncontrolled mobilization; DNAPL mobility is increased, not reduced; no underlying confining layer to prevent impacts to BFS • DDT is likely to precipitate and potentially foul permeable soils and wells	• Difficult to implement • Specialized chemicals and contractors are required • High concentration alcohols are flammable liquids requiring careful handling • Regulatory approval is required for alcohol injection • Separation of DNAPL at surface can be problematic	High	No
In-Situ Destructive Technologies	In-Situ Bioremediation (unsaturated zone)	Oxygen (or air) is delivered to the unsaturated zone to aerobically biodegrade MCB in-situ; this technology is commonly referred to as bioventing	• Potentially effective in biodegrading MCB; has not been bench or field pilot tested • MCB has relatively long half-life of approximately 150 days • MCB biodegradation rate may be slower than volatilization rate by SVE • Not effective in biodegrading DDT	• Implementable in permeable unsaturated soils • Potential risk of MCB volatilization and spreading • Difficult to implement in the low permeability PD soils	Low	No

TABLE 4.1 (continued)
Preliminary Screening of DNAPL Remedial Technologies and Process Options

General Response Action	Remedial Technology/ Process Option	Description	Technical Effectiveness	Implementability	Relative Cost	Retain for Assembly into Remedial Alternatives (Yes/No)
In-Situ Destructive Technologies (cont'd)	In-Situ Bioremediation (saturated zone)	Oxygen and mineral nutrients are delivered to the saturated zone to aerobically degrade MCB in-situ; microbial augmentation can also be implemented to enhance degradation rates	• Potentially effective in biodegrading dissolved-phase MCB causing DNAPL-phase MCB to solubilize in groundwater • Was bench tested in 1997; 38% MCB biodegradation in 4-week microcosm study • Naturally occurring bacteria may be sufficient to degrade MCB; bioaugmentation could be implemented to enhance population of MCB-degrading microorganisms if necessary • Additional testing required to verify effectiveness at high MCB concentrations present in source areas; biodegradation rate may be inhibited by MCB concentrations approaching solubility limit or high concentrations of DDT • Higher density of wells may be required to effectively deliver oxygen and mineral nutrients throughout heterogeneous UBA	• Implementable; highly implementable if combined with hydraulic displacement (using same infrastructure) • Oxygen and mineral nutrients are readily available and can be added to groundwater prior to re-injection • Highly skilled field operators are not required • Safe handling precautions may be required for hydrogen peroxide depending on concentration of source solution • Additional oxygen may be required to overcome oxygen demand of naturally occurring organics and minerals • Routine re-development of the wells may be required to restore hydraulic conductivities reduced by biofouling	Medium	No
In-Situ Thermal Technologies	In-Situ Chemical Oxidation (ISCO)	Oxidizing agents are injected into the saturated zone to destroy contaminants in-situ; common oxidizing agents include: permanganate, persulfate, peroxide, ozone, and Fenton's reaction	• Potentially effective (but uncertain) in oxidizing MCB; has not been bench or field pilot tested • Exceptionally large volume of oxidants would be required to remediate DNAPL mass in the saturated UBA • Higher density of wells may be required to effectively deliver oxidants throughout heterogeneous UBA • Precipitation of inorganics due to pH and/or redox changes may result in plugging of the aquifer	• Implementable • No ex-situ treatment required • Additional oxidants may be required to overcome oxidant demand of naturally occurring organics and minerals • Oxidant injection may displace DNAPL • Specialized chemicals and contractors are required	High	No

TABLE 4.1 (continued)
Preliminary Screening of DNAPL Remedial Technologies and Process Options

General Response Action	Remedial Technology/ Process Option	Description	Technical Effectiveness	Implementability	Relative Cost	Retain for Assembly into Remedial Alternatives (Yes/No)
In-Situ Thermal Technologies (cont'd)	Electrical Resistance Heating (ERH)	Soils are heated resistively by passing electrical current between a dense pattern of electrodes; VOCs are volatilized for removal by SVE and ex-situ vapor treatment; three technology vendors are available including TRS (three-phase heating), CES (six-phase heating), and McMillan-McGee (ET-DSP™)	• Potentially effective (but uncertain) in volatilizing MCB component of DNAPL; has not been bench or field pilot tested • Equally effective in treating low and high permeability soils • Heterogeneous nature of UBA may reduce effectiveness of recovering volatilized VOCs by SVE • Water influx from surrounding formation may result in cooling • 45-foot thick treatment interval will pose significant challenges for uniform heating • Full-scale system would be largest ERH project ever implemented • Has never been implemented on DNAPL primarily composed of MCB or DDT; relatively high MCB co-boiling point of 92°C may reduce effectiveness of ERH • Long-term hydraulic containment still required even if ERH was successful	• Difficult to implement • Large number of electrodes and associated infrastructure would be required • Requires implementation of SVE to recover VOCs for ex-situ vapor treatment • Requires skilled operators and high level of maintenance • High energy consumption and large carbon footprint • Three qualified ERH vendors available to implement	Very High	Yes
	Conductive Heating	Soils are heated conductively by a dense pattern of electric heater wells; one technology vendor is available, TerraTherm (ISTD™); wells are heated to more than 1,000°F to thermally oxidize VOCs in-situ	• Not effective in thermally treating Montrose DNAPL • TerraTherm has previously determined that ISTD results in excessive acid gas generation when treating organochlorine pesticides; severe equipment corrosion was experience at Rocky Mountain Arsenal site	• Not implementable due to the corrosive effects of the acid gas on metal equipment and piping	Very High	No

TABLE 4.1 (continued)
Preliminary Screening of DNAPL Remedial Technologies and Process Options

General Response Action	Remedial Technology/ Process Option	Description	Technical Effectiveness	Implementability	Relative Cost	Retain for Assembly into Remedial Alternatives (Yes/No)
In-Situ Thermal Technologies (cont'd)	Steam Injection	Pressurized steam is injected into the saturated zone to volatilize VOCs and flush DNAPL towards recovery wells; DNAPL, steam condensate, and VOCs are recovered from multiphase extraction wells positioned around the steam injection points; soil vapors and groundwater are treated ex-situ and DNAPL is disposed off-Site	• Potentially effective (but uncertain); has not been bench or field pilot tested • Steam injection is infrequently applied relative to ERH and conductive heating • Steam will preferentially flow through permeable soil layers; low permeability layers may not be effectively heated • Controlling the distribution of steam may be problematic; increased potential for lateral spreading, including below adjacent industrial warehouse at former Boeing Property • Increased potential for downward mobilization of DNAPL and steam condensate • The effectiveness of a hot floor in reducing the potential for downward mobilization is uncertain; large-scale steam injection hot floor has never been implemented • Full-scale system would be one of the largest steam injection projects ever implemented • Has never been implemented on DNAPL composed primarily of MCB and DDT; no comparable sites • Long-term hydraulic containment still required even if steam injection was successful	• Difficult to implement • Large number of steam injection/multiphase extraction wells and associated infrastructure would be required • Requires implementation of SVE to recover VOCs for ex-situ vapor treatment • Requires implementation of groundwater extraction to recover steam condensate and DNAPL for ex-situ treatment and disposal • Implementation of hot floor in BFS is required to reduce potential for downward migration • Requires highly skilled operators and a high level of maintenance, including boiler maintenance and brine disposal • High energy consumption and large carbon footprint • Limited availability of qualified steam injection vendors; few vendors still pursuing steam injection as commercial technology	Very High	Yes
Ex-Situ Groundwater Treatment	Liquid-Phase Granular Activated Carbon and Advanced Oxidation	Extracted groundwater would be treated to remove dissolved VOCs by liquid-phase granular activated carbon (LGAC) and pCBSA by advanced oxidation (e.g. APT HiPOx™.	• Effective • Treatment technologies identified in Groundwater ROD • Bench and field pilot tests confirm effectiveness in treating VOCs by LGAC and pCBSA by HiPOx™	• Implementable • Will be implemented as part of groundwater remedy	High	Yes

TABLE 4.1 (continued)
Preliminary Screening of DNAPL Remedial Technologies and Process Options

General Response Action	Remedial Technology/ Process Option	Description	Technical Effectiveness	Implementability	Relative Cost	Retain for Assembly into Remedial Alternatives (Yes/No)
Ex-Situ Vapor Treatment	Thermal Oxidation with Acid Gas Scrubbing	Extracted soil vapors are thermally oxidized at temperatures exceeding 1,500°F to destroy VOCs; acid gases are scrubbed and neutralized.	• Effective • Able to achieve high levels of contaminant destruction • Will meet SCAQMD emission standards	• Implementable • May require analysis for products of incomplete combustion • Requires skilled operators and high level of maintenance	Medium to High	Yes
	Regenerable Carbon/Resin Adsorption	Extracted soil vapors are passed through beds of carbon/resin to remove VOCs by adsorption; beds are thermally reactivated on-Site using low pressure steam; VOCs are condensed and captured for off-Site disposal	• Effective • Captures contaminants by adsorption • Will need more than one vessel connected in series to meet SCAQMD emission standards	• Implementable • Low volume of spent carbon to manage and dispose • Requires skilled operators and high level of maintenance	Medium to High	Yes
	Disposable Carbon/Resin Adsorption	Extracted soil vapors are passed through beds of carbon/resin to remove VOCs by adsorption; the spent carbon/resin is transported for off-Site disposal/reactivation and replaced with virgin material	• Effective • An MCB adsorption efficiency of 25% by weight was observed during 2003 SVE pilot test • Will need more than one vessel connected in series to meet SCAQMD emission standards	• Implementable • High volume of spent carbon to manage and dispose • Does not require highly skilled operators or high level of maintenance	Medium to High	Yes
Disposal	Injection of Treated Water as part of Groundwater Remedy	Extracted groundwater would be treated to remove dissolved VOCs and pCBSA and transferred to the Groundwater Remedy Treatment System for re-injection into the BFS and Gage Aquifers	• Effective • Applicable for thermal technologies where water re-injection could cool the saturated UBA	• Implementable • Would need to meet groundwater re-injection criteria specified in ROD • Would need to be considered by Groundwater RD	High	Yes
	Injection of Treated Water as part of Hydraulic Displacement	Extracted groundwater would be treated to remove dissolved VOCs and pCBSA prior to re-injection into the saturated UBA	• Effective • Enhances hydraulic gradient and DNAPL displacement • Treatment not required for hydraulic displacement	• Implementable • Would meet groundwater re-injection criteria specified in ROD	High	No

TABLE 4.1 (continued)
Preliminary Screening of DNAPL Remedial Technologies and Process Options

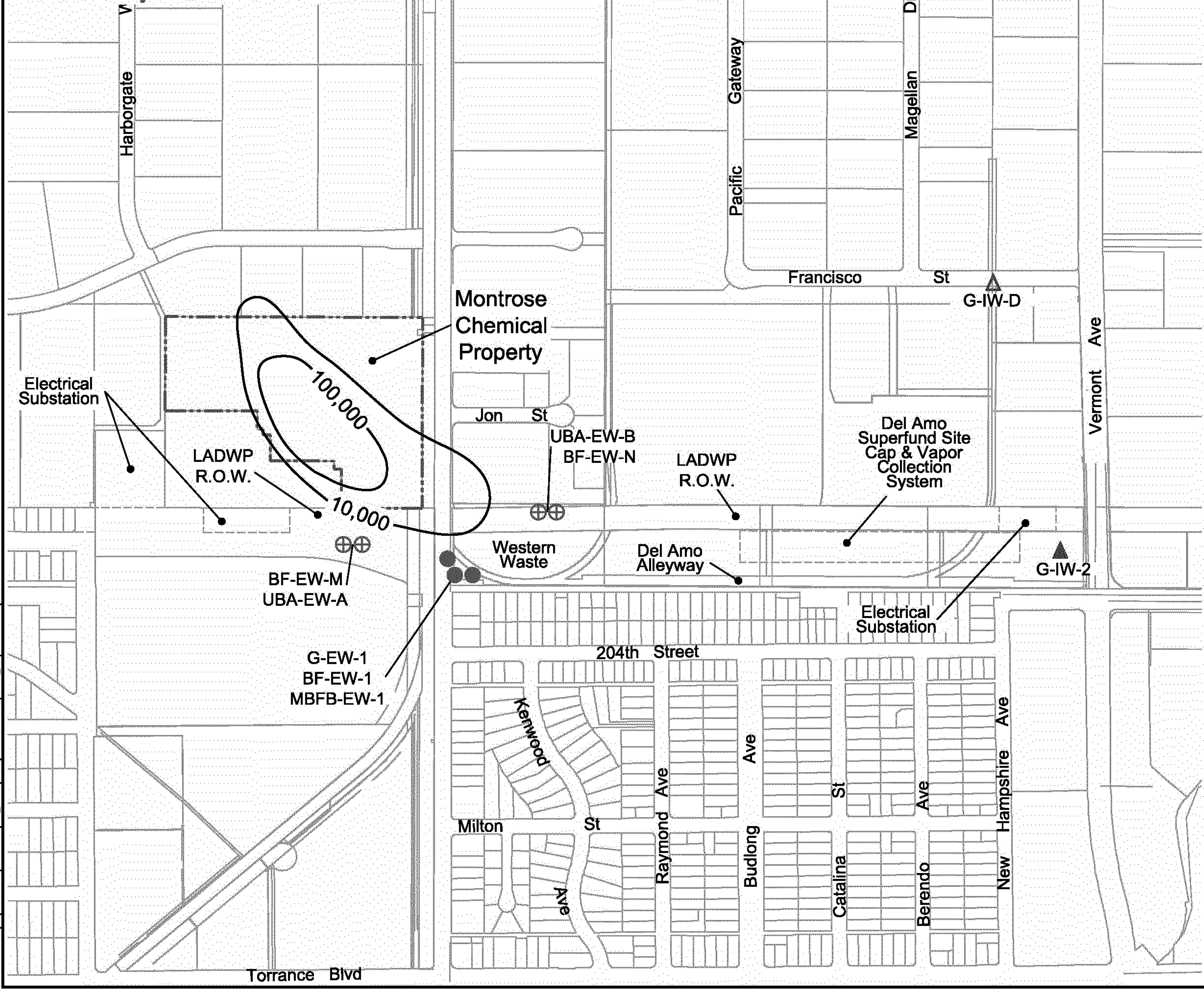
General Response Action	Remedial Technology/ Process Option	Description	Technical Effectiveness	Implementability	Relative Cost	Retain for Assembly into Remedial Alternatives (Yes/No)
Disposal (cont'd)	Injection of Untreated Water as part of Hydraulic Displacement	Extracted groundwater would be filtered and re-injected without treatment to remove dissolved VOCs and pCBSA	• Effective • Treatment for dissolved VOCs and pCBSA not required for hydraulic displacement of DNAPL	• Implementable • Groundwater ROD re-injection criteria would need to be waived	Low	Yes
	Off-Site Incineration of DNAPL	Recovered DNAPL would be transported for off-Site incineration	• Effective	• Implementable • Current disposal option used for DNAPL	High	Yes

Notes:

DNAPL = Dense Non-Aqueous Phase Liquid
DDT = Dichlorodiphenyltrichloroethane
MCB = Monochlorobenzene
pCBSA = para-Chlorobenzene sulfonic acid
UBA = Upper Bellflower Aquitard
BFS = Bellflower Sand
SVE = Soil vapor extraction
VOCs = Volatile organic compounds
ISCO = In-situ chemical oxidation
ERH = Electrical resistance heating
ISTD = In-situ thermal destruction
SEAR = Surfactant-enhanced aquifer remediation
LGAC = Liquid-phase granular activated carbon
ROD = Record of Decision
SCAQMD = South Coast Air Quality Management District
°F = Degrees Fahrenheit

FIGURES

Draft Subject To Revision



Legend:

Location of Current Montrose Property Boundary

Well Legend:

- Existing Extraction Well
- Existing Injection Well
- Proposed Extraction Well
- Proposed Injection Well

Well Identifiers:
EW = Extraction Well
IW = Injection Well
UBA = Upper Bellflower Aquitard
MBFB = Middle Bellflower B Sand
BF = Bellflower Sand
G = Gage Aquifer

10,000 Contour Line Reflects Dissolved Monochlorobenzene in Micrograms per Liter, shown in the UBA. Source: Hargis + Associates, Inc. 2007a.

Note:

1. Containment is also required in the BFS and Gage but those contours are not shown.
2. Source: Environmental Protection Agency, 2008b.

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works Bureau of Engineering Online ArcInfo GIS database, Copyright 2007. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, Copyright 2006. TerraServer Georeferenced Imagery, Copyright 2004.
3. Additonal base map information are based and from Hargis & Associates map dated August 2008, file name 410–6730.dwg.
4. Proposed locations are approximate, not for construction use.

NORTH
0 200 400 FEET
SCALE: 1"= 400'

Montrose Chemical Corporation

Containment Well Location Map

Date: 02-09 | Montrose Superfund Site | Figure 4.1
Project No. 103960 | EARTH TECH | AECOM

FILE NAME:Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0209\DNAPL_FS\SECTION 4.0\DNAPL-FS.SEC 4.0.FIG 4.1.020809.DWG

BOE-C6-0059806

Section 5.0

Assembly and Screening of Remedial Alternatives

5.0 ASSEMBLY AND SCREENING OF REMEDIAL ALTERNATIVES

The purpose of this section is to assemble remedial alternatives (RA) using the GRA remedial technologies and process options retained following the preliminary screening in Section 4.0. Once the RAs are assembled, they are evaluated against the same three performance criteria used in Section 4.0 as an intermediate screening step. RAs that are retained following this intermediate screening are then evaluated in detail, in Section 6.0, against the nine performance criteria identified in the NCP.

5.1 ASSEMBLY OF REMEDIAL ALTERNATIVES

The eight remedial technologies retained following preliminary screening have been assembled into six RAs. The RAs are assembled such that each successive RA potentially provides a higher level of DNAPL mass removal. The least amount of Site remediation is provided by RA 1, while RAs 5 and 6 could potentially provide the most mass removal. For RAs 5 and 6, each include two different process options; therefore, the RAs are split into two different alternatives for separate evaluation (e.g. RA 5a and 5b). The RAs assembled for evaluation in this section are summarized below:

Summary of Assembled Remedial Alternatives

Remedial Alternative	GRA Remedial Technologies/Process Options
Remedial Alternative 1	No Action Containment (required by Groundwater ROD)
Remedial Alternative 2	Containment (required by Groundwater ROD) Institutional Controls
Remedial Alternative 3	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone)
Remedial Alternative 4	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) Hydraulic Displacement, with untreated water injection
Remedial Alternative 5a	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) Steam Injection, focused treatment area, with hot floor

Remedial Alternative	GRA Remedial Technologies/Process Options
Remedial Alternative 5b	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) Steam Injection, entire treatment area, with hot floor
Remedial Alternative 6a	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) ERH, focused treatment area, without hot floor
Remedial Alternative 6b	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) ERH, entire treatment area, without hot floor

Three soil vapor treatment and three groundwater disposal process options were each retained following preliminary screening in Section 4.0. While these treatment/disposal process options are not uniquely identified in the above list of RAs, they are discussed in the following description of the RAs where appropriate. In the following sections, a detailed description and conceptual design for each of the assembled RAs is provided. In order to evaluate and compare these candidate RAs for compliance with global warming TBCs specified in Section 3, the carbon footprint (i.e., equivalent quantity of greenhouse gases) of each RA was estimated. The carbon footprint of each candidate RA is presented in this section, and detailed supporting calculations are provided in Appendix H.

5.1.1 REMEDIAL ALTERNATIVE 1 – NO ACTION

This RA includes the following two remedial technologies and process options:

No Action

Under this alternative, no action would be taken to reduce DNAPL mass or mobility, or comply with the DNAPL RAOs, other than those actions required by the groundwater and soil remedies. This no action alternative was assembled in accordance with EPA protocols for establishing a baseline alternative against which the other RAs will be compared.

<u>Containment</u>

Hydraulic containment is a requirement of the Groundwater remedy as specified in Provision 8 of the ROD, as follows: "*Containment of the chlorobenzene plume within the containment zone shall be affected by hydraulic extraction of groundwater from one or more extraction wells, followed by treatment of extracted water, followed by aquifer injection of the treated water through one or more injection wells*". Hydraulic containment within the TI Waiver Zone is required for the saturated UBA, the BFS, and the Gage Aquifer, and is accomplished through groundwater extraction and hydraulic gradient control.

Containment System Design

The fundamental design of the hydraulic containment program was specified in the EPA Model Development Report (EPA, 2008c) and includes three UBA, three BFS, and one Gage extraction wells. These wells will be located immediately downgradient of the DNAPL source areas at the locations shown in Figure 4.1. These wells will extract groundwater at an approximate combined rate of 200 to 250 gpm to contain dissolve-phase contaminant migration (primarily MCB). Dissolved contaminants in the groundwater will be treated ex-situ using LGAC (and possibly advanced oxidation) prior to re-injection. Once the groundwater restoration is completed, the treated water from the containment wells will be injected into the Gage aquifer through two groundwater remedy injection wells as shown in Figure 4.1.

Dissolved contaminants within the DNAPL-impacted UBA would be extracted and hydraulically contained from migrating downgradient. The horizontal hydraulic gradient would be controlled to ensure containment of the dissolved-phase MCB plumes, and the vertical hydraulic gradient would be controlled to reduce the potential for downward migration of DNAPL or dissolved-phase MCB. This process option is a required element of the groundwater remedy.

Operational Timeframe

Hydraulic containment would be initiated at the beginning of groundwater remedy startup and would conclude once the rate of dissolution from the DNAPL source is reduced to a level that no longer impacts groundwater in concentrations exceeding the ROD standards (70 ug/L for MCB) downgradient of the TI Waiver Zone. The duration required for hydraulic containment was estimated by H+A in a technical memorandum dated September 4, 2008 (H+A, 2008e). The containment timeframes estimated in the aforementioned H+A memorandum were based on the average DNAPL mass in the saturated UBA (average of conservative [minimum] and liberal [high] estimates). As explained in Section 2.5.4, in response to EPA comments, only the liberal DNAPL mass is presented in this FS. Therefore, the containment timeframes were re-estimated using only the liberal DNAPL mass as the basis, and a revised H+A memorandum is provided as **Appendix G** in this FS (H+A, 2009c). In this revised memorandum, three different MCB mass reduction percentages were assumed (60%, 80%, and 90%) for each of the RAs under consideration. These mass reduction assumptions apply to the DNAPL-phase MCB and exclude dissolved-phase MCB. The revised estimates for hydraulic containment timeframes using only the liberal DNAPL mass and the 60% to 90% mass reduction assumptions are presented in Appendix G and excerpted as follows to assist with the operational timeframe discussion:

Estimated Containment Timeframes at Varying MCB Mass Removal Assumptions

DNAPL Remedy Component in Saturated UBA	MCB Mass Removal (pounds)	Containment Timeframe (years)
Hydraulic Containment (RAs 1, 2, 3)	0	4,900
Hydraulic Displacement (RA 4)		
60% Mass Removal – mobile	66,550	4,700
80% Mass Removal – mobile	88,700	4,700
90% Mass Removal – mobile	99,800	4,700
Thermal Remediation, Focused Treatment Area (RAs 5a, 6a)		
60% Mass Removal	142,100	4,500
80% Mass Removal	189,500	4,400
90% Mass Removal	213,100	4,300
Thermal Remediation, Entire DNAPL-Impacted Area (RAs 5b, 6b)		
60% Mass Removal	238,800	4,200
80% Mass Removal	318,400	3,600
90% Mass Removal	358,200	3,100

If no action is taken to accelerate the rate of DNAPL mass reduction, the duration of hydraulic containment is estimated to be approximately 4,900 years. An exceptionally large amount of the DNAPL mass would have to be removed to have a meaningful impact on containment duration. Varying amounts of accelerated DNAPL mass removal may reduce the duration of hydraulic containment to between 3,100 and 4,700 years. Under any reasonable accelerated DNAPL mass removal assumption, hydraulic containment will be required for a very long duration. Unless timeframes could be reduced to the low hundreds of years or less (e.g., <100 years), there is no meaningful reduction in containment timeframe offered by any of the accelerated DNAPL RAs.

The primary benefit of removing DNAPL mass in the short-term is to reduce the duration required for long-term containment following the groundwater remedy, but based on this evaluation, it will not be technically feasible to remove a sufficient amount of DNAPL to meaningfully reduce the containment duration. Furthermore, although some level of uncertainty exists in certain of the selected input parameter values, the sensitivity analysis that H+A conducted bounds the probable range of values, and selected values generally provide low-end estimates of timeframe. Under any reasonable assumptions, the containment timeframe will exceed 1,000 years and likely more than 3,000 years (containment timeframes under 100 years is technically impracticable). The cost-benefit of applying aggressive source zone remediation must be considered given the exceptionally long duration required for hydraulic containment even after implementation of a DNAPL source zone remedy.

A thermal remedy removing 60% to 90% of the DNAPL-phase MCB mass over the entire DNAPL-impacted area, for example, still requires 3,100 to 4,200 years of containment. Given the complexities of the Site lithology and the unique nature of the Montrose DNAPL, there is no reliable evidence that a thermal remedy would be successful in removing up to 90% of the MCB mass. Removal of even 80% to 90% of the MCB mass is considered an optimistic, high-end assumption for mass removal at the Site. It is noted that only 64% of the MCB mass was removed during 2-dimensional bench-scale testing as described in Section 2.6.6. Only 84% of the PCE mass was removed during 2-dimensional bench-scale testing associated with the Solvents Recovery Service of New England site (She and Sleep, 1999).

While the thermal remediation technologies preferentially remove the volatile or MCB component of the DNAPL, the DDT component of the DNAPL is, for the most part, left behind. Although the DDT component does not contribute to the hydraulic containment timeframe, it is noted that hydraulic displacement works within the existing DNAPL architecture to remove mobile DNAPL composed of both MCB and DDT. Approximately 88,700 pounds of DDT would be removed by hydraulic displacement under RA 4, assuming 80% mass removal efficiency, which would otherwise be left in-situ by RAs 5a and 6a.

Additionally, fine-grained low permeability layers can store significant amounts of dissolved-phase mass which is released very slowly over time (i.e., back diffusion), even after DNAPL in the source zone has been removed. Although the methods used to estimate containment timeframes do not consider back diffusion, the containment timeframes are not expected to be significantly under-estimated since DNAPL dissolution over thousands of years is a more significant driving factor than back diffusion.

While institutional controls are not part of this RA, two of the process options associated with that GRA would be implemented as part of the Groundwater remedy, including:

> <u>Limiting Groundwater Use:</u> Limitations on groundwater and Site use would be implemented in the form of deed restrictions to prevent exposure to groundwater impacted by DNAPL constituents, specifically MCB.

Groundwater Monitoring: Groundwater monitoring would be implemented as part of the groundwater remedy and would document the effectiveness of the containment program.

5.1.2 REMEDIAL ALTERNATIVE 2 – INSTITUTIONAL CONTROLS

This RA includes the following two remedial technologies and process options:

Containment

Hydraulic containment would be implemented as described in Section 5.1.1 and would be required for an estimated duration of approximately 4,900 years.

Institutional Controls

Institutional controls would be implemented to prevent access to DNAPL-impacted soils. A land use covenant (deed restriction) would be established to restrict future activities at the Property for industrial use only and to place limits on construction, excavation, or drilling activities. Access to the Site is currently restricted by perimeter fencing and warning signs. These access restrictions would continue as part of a formal site inspection and maintenance program. The two groundwater-related institutional controls identified in Section 5.1.1 would additionally be implemented as part of the groundwater remedy.

A soil remedy has not yet been selected for the Site, but it is anticipated that institutional controls will be required as part of the soil remedy to protect human health and the environment from exposure to shallow contaminated soil and soil gas. Institutional controls for DNAPL would be limited to DNAPL-impacted areas including the Montrose Property and potentially a small portion of the former Boeing Realty Corporation property to the north.

5.1.3 REMEDIAL ALTERNATIVE 3 - SVE

This RA includes the following three remedial technologies and process options:

Containment

Hydraulic containment would be implemented as described in Section 5.1.1 and would be required for an estimated duration of approximately 4,900 years.

Institutional Controls

Institutional controls would be implemented as described in Section 5.1.2.

<u>SVE (unsaturated zone)</u>

SVE would be implemented in the unsaturated zone between approximately 25 and 60 feet bgs, corresponding to the PVS (Palos Verdes Sand) and unsaturated UBA soil layers, where an estimated 261,000 pounds of MCB occurs. A relatively high percentage of the MCB is expected to be removed from the permeable unsaturated soils by SVE, and therefore, mass removal efficiencies of 90% and 95% were assumed for this FS. Accordingly, between 234,900 and 248,000 pounds of MCB may be removed from the unsaturated zone by SVE under RA 3.

As described in Section 2.6.4, SVE was found to be effective in removing VOCs during pilot testing conducted in 2003. MCB and chloroform were the predominant VOCs recovered during the pilot test. Moderate to large vacuum influences were observed within these two zones during pilot testing, with estimated effective radius of vacuum influences of 64 and 123 feet.

SVE Wellfield

The conceptual design of the SVE system would include a series of extraction wells positioned throughout the VOC and DNAPL-impacted unsaturated zone. The spacing between wells would be based on the ROIs but allowing for some overlap to ensure that all unsaturated soils in these two layers are effectively evacuated. Because the two zones exhibited different flow properties, two sets of wells would be installed to separately evacuate the PVS and unsaturated UBA as shown in **Figures 5.1 and 5.2**. The estimated number of SVE wells required to evacuate the PVS and UBA are 7 and 16 wells respectively as shown in these figures. For the purpose of this FS, the SVE wells are assumed to be screened uniquely within each of the soil layers and not extend across more than one layer (i.e. 25-45 feet bgs for PVS wells and 45-60 feet bgs for UBA wells). An aboveground piping network would connect the SVE wells to an ex-situ extraction and treatment system located at the Property.

SVE Treatment System

Soil vapors would be extracted using either a positive displacement or liquid-ring vacuum blower. Suspended solids would be filtered, and entrained moisture would be separated or condensed. Soil vapors would then be passed to a treatment system for removal or destruction of the VOC contaminants prior to atmospheric discharge. A process flow diagram of the conceptual SVE system is provided as **Figure 5.3**. Three different soil vapor treatment process options were retained following preliminary screening in Section 4.8, including disposal GAC/resin, steam-regenerable GAC/resin, and thermal oxidation with acid-gas scrubbing. Both of the GAC/resin-type process options remove the VOC contaminants from the vapor stream via adsorption. The thermal oxidation process options destroy the VOC contaminants at elevated temperatures, converting them to carbon dioxide, water vapor, and acid gas. The acid gas is subsequently quenched and pH neutralized prior to discharge. Based on the number of wells identified in Figures 5.1 and 5.2, the estimated total SVE flow rate would be approximately 1,500 scfm.

Limitation to Application to Lithologic Zones

This conceptual approach to implementing SVE at the Property excludes VOC-impacted soils in the PD (Playa Deposits; 4 to 25 feet bgs). Soils within the PD are composed primarily of silts/clays and exhibited low permeabilities during SVE pilot testing in 2003. An elevated vacuum of approximately 18 inches of mercury was required to initiate soil vapor flow within the PD, following which a significant amount of vertical influence with the higher permeability, underlying PVS was observed. The pilot test results from the PD reflect a combination of soil vapors from both the PD and PVS, and therefore, it was not possible to uniquely distinguish the potential effectiveness of the SVE within the PD. However, SVE is expected to be significantly less effective in low permeability soils such as the PD. For this reason, the conceptual design of the SVE system excludes soils within the PD. As part of the Soil FS, control of vapors near land surface from the PD is being evaluated.

Estimated Operational Time Period

SVE operations would continue for a period of approximately 3 to 5 years and until VOC concentrations in soil gas had declined to low asymptotic levels (i.e., not cost effective to continue SVE operations). An example first order exponential decline curve is provided as **Figure 5.4**, showing MCB mass in the unsaturated zone asymptotically approaching zero in Year 4. At that time, soil borings would be drilled and samples collected to verify the effectiveness of the SVE remedy in the unsaturated zone. Residual VOC concentrations in soil would be compared against EPA Region 9 PRGs, risk-based cleanup goals, or leaching model-based cleanup goals. VOCs from the overlying low permeability PD and underlying groundwater surface will slowly volatilize into soil gas during SVE operations, even though these VOC sources are not the objective of the SVE remedial action. Therefore, the decision criteria for terminating SVE operations in the PVS and unsaturated UBA would be based on the sorbed concentration of VOCs remaining in these layers, the vertical concentration trend in the target treatment zone, the VOC mass removal rate, and the cost-benefit of continuing SVE operations.

Operational Implications

The SVE component of this RA, excluding hydraulic containment, is expected to consume approximately 4,700 megawatt-hours in electricity. The carbon footprint (i.e., equivalent quantity of greenhouse gases) of this RA is estimated to be 2.2 million pounds of carbon dioxide. An estimated 14,200 trees would be required to offset this mass of carbon dioxide production (i.e., via photosynthesis). The carbon footprint calculation for this RA is provided in **Appendix H**, and a summary of the carbon footprints for all the RAs is provided in **Table 5.1**.

5.1.4 Remedial Alternative 4 – Hydraulic Displacement with Untreated Water Re-Injection

This RA includes the following four remedial technologies and process options:

Containment

Hydraulic containment would be implemented as described in Section 5.1.1 and would be required for an estimated duration of approximately 4,600 to 4,700 years.

Institutional Controls

Institutional controls would be implemented as described in Section 5.1.2.

SVE (unsaturated zone)

SVE would be implemented in the unsaturated zone as described in Section 5.1.3.

Hydraulic Displacement, with untreated water re-injection

Hydraulic displacement would be implemented within the saturated UBA to remove mobile DNAPL. The conceptual design of a hydraulic displacement RA was previously reconciled with EPA during a conference call held on February 21, 2008. Additionally, it is noted that groundwater would be re-injected into the UBA under this RA, rather than into the BFS and Gage Aquifer. Therefore, implementation of this RA would not affect the design or operation of the Groundwater Remedy Treatment System.

Area of Application

A series of groundwater/DNAPL extraction wells and groundwater injection wells would be positioned throughout the DNAPL-impacted area where mobile DNAPL is believed to occur, which is approximately 22,900 square feet as shown in **Figure 5.5**. This area was estimated based on the known occurrence of mobile DNAPL in source area wells and DNAPL concentrations in saturated UBA soils exceeding 53,000 mg/kg. This concentration is equivalent to a DNAPL saturation of 18.9%, which was determined to be the minimum residual DNAPL saturation in one soil core as described in Section 2.1.2. The concentration is additionally based on the average effective porosity and wet soil density of sand layers measured during physical properties testing of soils collected at boring 2DSB-1.

As area surrounding SSB-12, of approximately 3,100 square feet, is additionally included as part of the conceptual design for this hydraulic displacement RA. An elevated DNAPL concentration of 103,000 mg/kg was measured in a 82.5-foot bgs soil sample at this location (Section 2.5.6), but the presence of mobile DNAPL at this remote location was unexpected and was investigated in December 2008. A short-term hydraulic extraction test was conducted at well UBE-5, located adjacent to SSB-12, which confirmed the presence of mobile DNAPL at this location. DNAPL was recovered from UBE-5 at a peak rate of 0.8 liters per hour during the short-term field test.

Assessment of Uncertainties

Residual DNAPL saturations are expected to vary at the Site, have not been measured with the exception of one soil core, and are uncertain. Therefore, the area assumed for implementation of a hydraulic displacement RA is an estimate developed for the purpose of this FS, and some level of uncertainty is associated with the estimated mass of mobile DNAPL at the Site. If the true average residual DNAPL saturation at the Site is above 18.9%, then the mass of mobile DNAPL (and RA 4 remedy costs) presented in this FS will be over-estimated. Similarly, if the true average residual DNAPL saturation at the Site is below 18.9%, then the fraction of DNAPL mass that is mobile would be higher. Dr. Bernie Kueper of Queen's University in Ontario, Canada, has indicated (based on his experience) that the average residual saturation at the Site is unlikely to be lower than the assumed 18.9% value. Dr. Kueper has indicated that an average residual DNAPL saturation at the Site is more likely to be approximately 25%.

In spite of the uncertainties related to residual DNAPL saturations, the estimated extent of mobile DNAPL at the Site is supported by field evidence. Through passive DNAPL accumulation and extraction testing, mobile DNAPL has been observed in seven wells, all of which occur within the estimated mobile

DNAPL extent. Additionally, no mobile DNAPL has been observed at wells UBE-2 and UBE-3, which occur outside the estimated extent of mobile DNAPL. The physical evidence at the Site corroborates the estimated extent of mobile DNAPL based on DNAPL concentrations and an assumed residual saturation.

Hydraulic Displacement System Description

The extraction and injection wells would be positioned in a 5-spot type pattern, with four extraction wells surrounding one injection well. Injection wells would additionally be positioned around the perimeter of the treatment area to hydraulically flush mobile DNAPL inwards, towards the recovery wells. A conceptual hydraulic displacement well pattern using a 50-foot well spacing is provided as **Figure 5.6** and includes 18 extraction wells and 23 injection wells (including the isolated area surrounding boring SSB-12). The spacing of 50-feet between extraction wells was reconciled during a scoping conference call held on February 21, 2008 between EPA and Montrose is assumed based on the following rationale:.

> H+A and Intera evaluated various well spacings as part of the hydraulic displacement modeling (H+A, 2009b), and the modeling results indicated that a well spacing of 120 feet or less would be required to effectively displace mobile DNAPL for extraction. The preliminary modeling results support selection of a 50-foot well spacing for this hydraulic displacement conceptual design. All wells would be screened across the DNAPL-impacted interval ranging from approximately 60 to 100 feet bgs depending on the occurrence of DNAPL accumulation, and the extraction wells would additionally be constructed with a 5-foot sump at the bottom for DNAPL or solids accumulation. Conceptual well construction diagrams for the extraction and injection wells are provided as **Figures 5.7 and 5.8**.

Operations and Treatment

A process flow diagram of the conceptual hydraulic displacement system is provided as **Figure 5.9**. Groundwater would be extracted at a rate of approximately 7 to 10 gpm per well (based on 2004/2005 field pilot test) using electric submersible pumps and transferred via an aboveground piping network to a DNAPL/water separator. Separated water would be filtered to remove suspended solids and then re-injected without further treatment to remove dissolved VOCs. A combined groundwater extraction and re-injection rate of approximately 150 gpm is assumed for this hydraulic displacement RA.

Recovered DNAPL would be transferred to a collection tank and transported for off-Site disposal every 90 days or less. DNAPL accumulating in the sump of the groundwater extraction well would be extracted using low flow pneumatic bladder pumps and discharged to a gravity separator (decanter). Separated

DNAPL would be transferred to the collection tank for subsequent off-Site disposal, and separated groundwater would be transferred to the groundwater/DNAPL separator for subsequent filtering and re-injection.

Operational Duration

The duration of a hydraulic displacement remedy is assumed to be approximately 5 years, as reconciled with EPA in February 2008. Because groundwater is re-injected into the UBA, implementation of this RA would not impact the design or operation of the Groundwater Remedy Treatment System.

Approximately 21,000 gallons of mobile DNAPL (221,800 pounds of DNAPL or approximately 110,000 pounds of MCB) is estimated to be contained within the saturated UBA as shown in Appendix E. The liberal mass estimate of DNAPL in the UBA (residual plus mobile) was estimated to be 796,100 pounds respectively as described in Section 2.5.5, and therefore, approximately 28% of the DNAPL in the UBA is believed to be present in potentially mobile saturations. This estimate is based on DNAPL concentrations (sum of MCB and Total DDT) in soil measured during investigation activities in 2003-2005 (H+A, 2004b and 2006a) and an assumed residual DNAPL saturation of 18.9% (assumed to be constant throughout the UBA).

It is recognized that residual DNAPL saturations will vary throughout the UBA and that there is a limited amount of DNAPL concentrations in soil upon which to base the estimate. Although there is uncertainty associated with the volume/mass of mobile DNAPL in the UBA, the aforementioned estimate is considered reasonable, consistent with the estimated mass of DNAPL at the Site, and acceptable for purposes of this FS. DNAPL/water capillary pressure testing (Section 2.1.2 and Appendix B) suggests that elevated capillary pressures would be required to displace the final 1% to 1.5% of mobile DNAPL (e.g., 18.9% to 20.4% DNAPL saturations). Therefore, high mass removal efficiencies approaching 100% are unlikely for RA 4.

Additionally, some DNAPL may sorb to pore spaces as it is moves through the porous soils to the extraction wells, even though water is believed to be the wetting fluid (i.e., water will preferentially wet the pore surfaces over the DNAPL). Since some of the DNAPL may sorb to soil grains during the displacement process, mass removal efficiencies over 90% are also unlikely for HD. A relatively high well density reduces the distance that the DNAPL must travel to reach the extraction well and would be expected to result in a higher mass removal efficiency (i.e., less of an opportunity for DNAPL to sorb to soil grains before reaching the extraction well). However, an 80% mobile DNAPL mass removal efficiency is considered reasonable for RA 4, particularly if a high well density scenario is used for this

RA. Assuming 80% mobile DNAPL mass reduction, an estimated 177,400 pounds of liquid-phase DNAPL (MCB+DDT) would be removed by RA 4. Assuming that MCB represents 50% of the DNAPL mass, the estimated amount of MCB mass reduction under RA 4 would therefore be 88,700 pounds.

Although computer modeling predicts that the proposed 50-foot well spacing for hydraulic displacement will be effective, the geostatistical evaluation conducted in advance of the modeling activities (H+A, 2008d) suggested that a well spacing under 50 feet may be more effective for the Site because of geologic layer discontinuities. Because hydraulic displacement is a relatively low to moderate cost technology, a higher well density may remain very cost effective, particularly for this RA which does not require ex-situ treatment of dissolved-phase contaminants prior to re-injection. Therefore, an alternate well spacing of 25-feet is additionally considered for hydraulic displacement at the Site. A conceptual hydraulic displacement well pattern using a 25-foot spacing is provided as **Figure 5.10** and includes 32 extraction wells and 37 injection wells (including isolated area surrounding SSB-12). The assumed combined groundwater extraction and re-injection rate would remain at 150 gpm, but on this smaller spacing, the extraction rate per individual well would be reduced to between 4 and 7 gpm.

The combination of SVE in the unsaturated zone and hydraulic displacement in the saturated UBA is expected to consume approximately 9,100 megawatt-hours of electricity. The equivalent carbon footprint of this RA is estimated at approximately 4.2 million pounds of carbon dioxide, requiring approximately 27,300 trees to offset the carbon dioxide production (Table 5.1 and Appendix H).

5.1.5 Remedial Alternative 5A – Steam Injection, Focused Treatment Area with Hot Floor

This RA includes the following four remedial technologies and process options:

Containment

Hydraulic containment would be implemented as described in Section 5.1.1 and would be required for an estimated duration of approximately 4,300 to 4,500 years.

Institutional Controls

Institutional controls would be implemented as described in Section 5.1.2.

SVE (unsaturated zone)

SVE would be implemented in the unsaturated PVS as described in Section 5.1.3. However, SVE within the unsaturated UBA is additionally a component of a steam injection RA and used to recover steam and volatilized VOCs from the underlying saturated UBA. Depending on depth, some of the SVE wells are used for both purposes. SVE from the PVS (25 to 45 feet bgs) remains the same as previously described in Section 5.1.3. However, the multiphase extraction wells used for a thermal remedy would be screened up to 45 feet bgs in the unsaturated zone, and therefore, SVE over the unsaturated UBA from 45 to 60 feet bgs is combined with the steam injection remedy as indicated below. Under this steam injection RA, installation of separate SVE wells within the unsaturated UBA, between 45 and 60 feet bgs, will not be required. Therefore, the cost of the SVE remedial component for this steam injection RA is reduced.

Steam Injection, Focused Treatment Area with Hot Floor

Steam injection would be implemented within the saturated UBA over a focused treatment area to thermally treat both residual and mobile DNAPL. The entire DNAPL impacted area is approximately 160,000 square feet, which is exceptionally large for thermal remediation alternatives and would be one of the four largest steam injection projects ever attempted in the United States as indicated in Section 4.6.3. However, based on thermal case study evaluations conducted by EPA and Montrose in 2007, the majority of thermal remediation projects treat areas between approximately 10,000 and 50,000 square feet.

As an alternative to address the problems with scale, a smaller focused treatment area of approximately 22,900 square feet was identified as shown in **Figure 5.11**. The focused treatment area also includes an isolated area of approximately 3,100 square feet surrounding boring SSB-12, shown in this figure, where mobile DNAPL is present. Candidate focused treatment areas were evaluated by Montrose in June 2008 based on varying DNAPL thickness and concentration criteria (Earth Tech, 2008b). That evaluation recommended the focused treatment area shown in Figure 5.11, which includes all areas believed to contain mobile DNAPL. While the focused treatment area represents only 16% of the entire DNAPL-impacted area, it contains approximately 60% of the estimated DNAPL mass in the saturated UBA (473,700 pounds). Although steam injection may remove some liquid-phase DNAPL, it would primarily remove the volatile MCB component of the DNAPL, leaving the DDT component behind (in-situ). Assuming that the MCB represents 50% of the DNAPL mass, an estimated 236,800 pounds of MCB is present in the focused treatment area and potentially subject to thermal remediation (although only a portion of this estimated mass would be recovered by steam injection). While the extent of DNAPL at the

Site is well documented, there is greater uncertainty related to the extent of mobile DNAPL. If the extent of mobile DNAPL is greater than currently represented by the focused treatment area, then the associated costs presented in this FS are under-estimated. Expansion of the focused treatment area would result in higher thermal remedy costs under RA 5a.

Evaluation of a focused treatment area where the contaminant mass is most heavily concentrated has been performed at other DNAPL sites. For example, at the Silresim Superfund Site in Lowell, Massachusetts, a focused treatment alternative targeting 65,000 cubic yards of DNAPL-impacted soil was selected over full-scale ERH alternatives targeting between 162,000 and 260,000 cubic yards. At that site, EPA determined that full-scale application of ERH was not cost effective, and selection of a focused treatment area was found to improve the cost effectiveness of thermal remediation alternatives.

EPA commented on the Focused Treatment Area Evaluation in correspondence dated September 10, 2008 (EPA, 2008d). While EPA did not necessarily concur with the rationale used in the evaluation, EPA did concur that the recommended focused treatment area reasonably encompassed the area believed to contain mobile DNAPL. EPA concurred with the recommended focused treatment area for use in this FS, although modifications to the focused treatment area may be required if actual conditions are found to be different from assumed conditions.

Conceptual Design of RA:

Montrose and EPA have been working to establish a conceptual approach (and costs) for the thermal remediation technologies considered for the Site since 2007. A series of reconciliation conference calls were held from December 2007 to February 2008. Based on these reconciliation discussions, Montrose prepared detailed scoping memorandums and cost estimates for various thermal remediation alternatives, which were submitted to EPA between July 21 and August 22, 2008 (Earth Tech, 2008c, 2008d, 2008e, and 2008f). Following review of the memorandums, EPA requested additional revisions to the scoping assumptions. The conceptual design for this steam injection RA is based on the results of those technical memorandums and associated EPA comments. As a result of cost reconciliation with EPA, a range of reasonable costs (i.e., both a low and high cost scenario) is presented in this FS for steam injection.

Pilot Test

No steam injection pilot has been conducted at the Site, and the relatively small size of the Focused Treatment Area does not readily lend itself to implementation of a pilot (a pilot test would cover approximately 50% of the focused treatment area). Therefore, no pilot test would be implemented under this focused treatment area RA.

Steam Injection and Multiphase Extraction Well Configuration:

Steam injection and multiphase extraction wells (groundwater, DNAPL, and soil vapors) would be installed throughout the focused treatment area in either a 5-spot or 7-spot pattern. A 5-spot pattern is composed of four multiphase extraction wells, in a square pattern, surrounding one steam injection well. A 7-spot pattern is composed of six multiphase extraction wells, in a hexagonal pattern, surrounding one steam injection well.

Wells would be spaced between 42 and 60 feet apart. Because the perimeter of the focused treatment area is still within the DNAPL-impacted area, the outer wells of the pattern would be extraction wells in order to recover any contaminants displaced away from the source area. Assuming a 5-spot well pattern with 42-foot spacing, 12 steam injection and 21 multi-phase extraction wells would be required as shown in **Figure 5.12**. Alternately, and as requested by EPA, assuming a 7-spot well pattern with 60-foot spacing, 10 steam injection and 18 multi-phase extraction wells would be required as shown in **Figure 5.13**. For this FS and as a result of cost reconciliation with EPA, the 7-spot well pattern was assumed for the low cost scenario while the 5-spot well pattern was assumed for the high cost scenario. The conceptual scope of work for this steam injection RA includes the area surrounding SSB-12, where mobile DNAPL was recently observed during a short-term field pilot test. An additional 1 to 2 steam injection wells and 6 multiphase extraction wells would be required to treat the area surrounding boring SSB-12.

Steam injection wells would be constructed using 2-inch diameter stainless steel casings, with three casings at each location (in the same borehole). The steam injection casings would be screened approximately as follows: 70 to 75, 85 to 90, and 100 to 105 feet bgs. A conceptual well construction diagram is provided as **Figure 5.14**. Because steam will flow preferentially through the highest permeability soil layers, the three independent casings at each location offer the ability to control the amount of steam delivered to each of the three intervals, as needed. The multiphase extraction wells will be constructed using 6-inch diameter casing, with one screened interval over the entire treatment zone from 45 to 105 feet bgs (both unsaturated and saturated UBA). A conceptual multiphase extraction well construction diagram is provided as **Figure 5.15**.

Hot Floor:

Due to the risk of downward DNAPL mobilization imposed by a steam injection RA, a hot floor would be implemented within the underlying BFS. The conceptual design for the hot floor includes 20 steam injection wells and 9 multiphase extraction wells spaced 60 feet apart in a 7-spot pattern (**Figure 5.17**). The wells would be installed using mud-rotary drilling methods to install permanent conductor casings to seal off the DNAPL-impacted zone and reduce the potential for DNAPL migration during drilling activities or within the annulus of the borehole. The wells would be screened from 110 to 115 feet bgs. Well construction diagrams for the conceptual hot floor wells are provided in **Figures 5.18 and 5.19**. Steam would be injected into the hot floor at least 30 days in advance of heating the UBA. Pre-heating of the hot floor would reduce the potential for downward migrating DNAPL to travel through the BFS, although some risk would remain. Upon entering the hot floor, any downward migrating DNAPL would be thermally treated (i.e., volatilization of the MCB component), providing that the hot floor was uniformly heated to target temperatures. Sufficient groundwater would be recovered from the multiphase extraction wells to off-set the cold water equivalent of the steam injected to reduce the potential for displacement and spreading of the dissolved contaminant plume within the BFS. It is noted that the hot floor at the Montrose Site would not be a clay, like many other sites, but would rather serve as a "thermal barrier", which has to prevent DNAPL from migrating into the BFS, a highly transmissive aquifer.

Treatment Volume:

Due to the irregular shape of the focused treatment area, the remediation well pattern covers an area larger than the target treatment area. The area within the well pattern is approximately 50,700 square feet versus the 22,900 square feet of the focused treatment area. With a treatment interval from 60 to 105 feet bgs, the target treatment volume for this RA would be 38,200 cubic yards within the saturated UBA. The treatment volume in the UBA surrounding boring SSB-12 is approximately 5,200 cubic yards, raising the total treatment volume for this RA to 43,400 cubic yards.

Energy Requirements:

Steam would be injected into each of the steam injection wells via an aboveground piping network. Flow control valves and meters would be provided at each of the injection well casings. One 29 million BTUs per hour (MM BTUs/hr) natural gas-fired steam boiler would be used to generate and deliver the required steam. For the focused treatment area, between 163,000 and 244,000 thousand cubic feet (MCF) of natural gas is estimated to be required depending on the number of equivalent pore volumes required to reach target temperature (i.e. cold water equivalent of cumulative steam flow). The energy requirements for the SSB-12 area are estimated at approximately 14,400 MCF of natural gas. Between 2 and 3 pore volumes of steam flushing, or more, is estimated to be required to reach target temperatures throughout the DNAPL-impacted zone.

The assumed energy requirements for this RA are based on an energy balance, calculated at the request of EPA and provided in **Appendix I**. Additionally, due to some uncertainty related to energy consumption by a steam remedy at the Site (no pilot test has been implemented), both low and high energy consumption estimates were calculated. The combined carbon footprint of SVE in the unsaturated zone and steam injection in the saturated UBA over a focused treatment area is estimated to generate 46 million pounds of carbon dioxide, requiring approximately 297,400 trees to offset the carbon dioxide production (Table 5.1 and Appendix H). This carbon footprint estimate is based on an average of the low and high energy balance assumptions.

The total duration of the RA would be approximately 4 years including design, construction, operation and maintenance, verification, and abandonment. The duration of the heating portion only is estimated to be 12 months. Once target temperatures and target pore volumes steam flushing are achieved throughout the DNAPL-impacted zone, steam injection operations would be terminated and verification borings would be drilled and samples collected to verify the performance of the remedy.

SVE and Ex-Situ Vapor Treatment:

Steam and heated soil vapors would be extracted from the multiphase phase for on-Site treatment. Approximately 750 scfm of soil vapors would be extracted using two liquid-ring vacuum blowers and cooled to condense the steam before being delivered to the vapor treatment system. Three soil vapor treatment process options were evaluated in Section 4.8, but steam-regenerable carbon/resin is particularly applicable to this RA because of the steam boiler required for the remedy. A process flow diagram of the conceptual steam injection remedial system is provided as **Figure 5.16**.

Ex-Situ Groundwater Treatment and Disposal:

Approximately 75 gpm of groundwater and steam condensate would be extracted from the multiphase wells for on-Site treatment. As described in Section 4.7, groundwater would be treated by a combination of LGAC to remove MCB and other VOCs by adsorption and HiPOx™ to destroy pCBSA by oxidation. Re-injection of the treated water is not fundamental to the steam injection remedy and may serve to cool the subsurface. For this reason, treated groundwater is assumed to be transferred to the Groundwater Remedy Treatment System for subsequent re-injection into the BFS and Gage aquifers (as evaluated in

Section 4.9). The remedial design for the Groundwater Remedy Treatment System would need to consider the treated groundwater flow transferred from this DNAPL RA.

DNAPL Disposal:

As specified in Section 4.7, all recovered DNAPL would be disposed off-Site every 90 days or less.

Temperature Monitoring Points:

Approximately 12 temperature monitoring points would be installed throughout the focused treatment area to monitor subsurface heating both laterally and vertically. At each temperature monitoring point, thermocouples would be positioned every 5 vertical feet from approximately 25 to 115 feet bgs, to monitor temperatures both above the treatment interval and below, within the hot floor.

5.1.6 Remedial Alternative 5b – Steam Injection, Entire DNAPL-Impacted Area with Hot Floor

This RA includes the following four remedial technologies and process options:

Containment

Hydraulic containment would be implemented as described in Section 5.1.1 and would be required for an estimated duration of approximately 3,100 to 4,200 years.

Institutional Controls

Institutional controls would be implemented as described in Section 5.1.2.

SVE (unsaturated zone)

SVE would be implemented in the unsaturated PVS as described in Section 5.1.3. However, SVE within the unsaturated UBA is additionally a component of a steam injection RA and used to recover steam and volatilized VOCs from the underlying saturated UBA. Depending on depth, some of the SVE wells are used for both purposes. SVE from the PVS (25 to 45 feet bgs) remains the same as previously described in Section 5.1.3. However, the multiphase extraction wells used for a thermal remedy would be screened up to 45 feet bgs in the unsaturated zone, and therefore, SVE over the unsaturated UBA from 45 to 60 feet bgs is combined with the steam injection remedy as indicated below. Under this steam injection RA, installation of separate SVE wells within the unsaturated UBA, between 45 and 60 feet bgs, will not be required. Therefore, the cost of the SVE remedial component for this steam injection RA is reduced.

Steam Injection, Entire DNAPL-Impacted Area with Hot Floor

Steam injection would be implemented within the saturated UBA over the entire DNAPL-impacted area to thermally treat both residual and mobile DNAPL. Steam injection would be implemented in the same manner as for the focused treatment area, except that treatment would apply to the entire 160,000 square foot DNAPL-impacted area where an estimated 796,100 pounds of DNAPL are estimated to occur. Assuming that the MCB represents 50% of the DNAPL mass, an estimated 398,000 pounds of MCB is present at the Site and potentially subject to thermal remediation (although only a portion of this estimated mass would be recovered by steam injection). The elements of the steam injection conceptual design are summarized as follows.

Pilot Test:

A pilot test would be implemented in advance of full-scale steam injection throughout the entire DNAPL-impacted area. As indicated in Section 4.6.3, implementation of steam injection throughout the entire DNAPL-impacted area at the Site would be one of the four largest thermal remediation projects ever implemented in the United States and potentially the most complex given the Site lithology and unique nature of the DNAPL. A steam injection pilot test has not been conducted at the Site to establish either the feasibility of the technology, or if feasible, initial design parameters. Therefore, under this RA, a pilot test is assumed to be conducted in advance of full-scale design. The pilot test would thermally treat an area of approximately 11,000 square feet and 18,300 cubic yards within the saturated UBA. Assuming a 5-spot pattern and a 42-foot well spacing, 3 steam injection and 8 multiphase extraction wells would be installed to conduct the pilot. A conceptual well pattern for the pilot test is provided in **Figure 5.20**. The pilot test would be conducted for a period of approximately 6 months. Pilot-scale boiler, SVE system, and groundwater treatment system would be employed for the test.

Steam Injection and Multiphase Extraction Wells:

Steam injection and multiphase extraction wells will be installed throughout the entire DNAPL-impacted area using the same well pattern and spacing indicated for the focused treatment area. Assuming a 5-spot pattern with 42-foot well spacing, a total of 61 steam injection and 53 multiphase extraction wells would be required (**Figure 5.21**). Assuming a 7-spot pattern with 60-foot well spacing, a total of 48 injection wells and 42 multiphase extraction wells would be required (**Figure 5.22**). The well pattern will extend just outside the estimated extent of DNAPL, and steam injection wells would be positioned to displace DNAPL inward towards the recovery wells. For this FS and as a result of cost reconciliation with EPA, the 7-spot well pattern was assumed for the low cost scenario while the 5-spot well pattern was assumed for the high cost scenario.

Hot Floor:

The conceptual design for the hot floor includes 55 steam injection wells and 22 multiphase extraction wells spaced 60 feet apart in a 7-spot pattern (**Figure 5.23**). The actual number of hot floor wells would be determined following completion of pilot testing as indicated above.

Treatment Volume:

The target treatment area is 160,000 square feet, and the treatment interval is from 60 to 105 feet bgs, consistent with the saturated UBA. Therefore, the target treatment volume for this RA would be 267,000 cubic yards within the saturated UBA.

Energy Requirements:

For the entire DNAPL-impacted area, between 594,000 and 891,000 MCF of natural gas is estimated to be required depending on the number of equivalent pore volumes required to reach target temperature. The assumed energy requirements for this RA are based on an energy balance, calculated at the request of EPA and provided in Appendix I. To deliver this volume of steam, two 29 MM BTUs/hr steam boilers are assumed to be required. The combined carbon footprint of SVE in the unsaturated zone and steam injection in the saturated UBA over the entire DNAPL impacted area is estimated to generate approximately 175 million pounds of carbon dioxide, requiring 1.1 million trees to offset the carbon dioxide production (Table 5.1 and Appendix H). This carbon footprint estimate is based on an average of the low and high energy balance assumptions.

Operations Duration:

The total duration is estimated to be 7 years including pilot testing, design, construction, operation and maintenance, verification, and abandonment. The duration of the heating portion only over the entire DNAPL-impacted area is estimated to be 24 months.

SVE and Ex-Situ Vapor Treatment:

Steam and heated soil vapors would be extracted from the multiphase phase for on-Site treatment. Approximately 2,000 scfm of soil vapors would be extracted using three liquid-ring vacuum blowers and cooled to condense the steam before being delivered to the vapor treatment system. A process flow diagram of the conceptual steam injection remedial system is provided as **Figure 5.24**.

Ex-Situ Groundwater Treatment and Disposal:

Approximately 200 gpm of groundwater and steam condensate would be extracted from the multiphase wells for on-Site treatment by LGAC and HiPOx™. Treated groundwater would be transferred to the Groundwater Remedy Treatment System for re-injection into the BFS and Gage Aquifers.

DNAPL Disposal:

All recovered DNAPL would be disposed off-Site every 90 days or less.

Temperature Monitoring Points:

Approximately 70 temperature monitoring points would be installed throughout the DNAPL-impacted area to monitor subsurface heating both laterally and vertically.

5.1.7 Remedial Alternative 6A – ERH, Focused Treatment Area without Hot Floor

This RA includes the following four remedial technologies and process options:

Containment

Hydraulic containment would be implemented as described in Section 5.1.1 and would be required for an estimated duration of approximately 4,300 to 4,500 years.

Institutional Controls

Institutional controls would be implemented as described in Section 5.1.2.

SVE (unsaturated zone)

SVE would be implemented in the unsaturated zone as described in Section 5.1.3. However, SVE within the unsaturated UBA is additionally a component of an ERH RA and used to recover volatilized VOCs from the underlying saturated UBA. Depending on depth, some of the SVE wells are used for both purposes. SVE from the PVS (25 to 45 feet bgs) remains the same as previously described in Section 5.1.3. However, the multiphase extraction wells used for a thermal remedy would be screened up to 45 feet bgs in the unsaturated zone, and therefore, SVE over the unsaturated UBA from 45 to 60 feet bgs is combined with the ERH remedy as indicated below. Under this ERH RA, installation of separate SVE wells within the unsaturated UBA, between 45 and 60 feet bgs, will not be required. Therefore, the cost of the SVE remedial component for this ERH RA is reduced.

ERH, Focused Treatment Area without Hot Floor

ERH would be implemented within the saturated UBA over a focused treatment area of 26,000 square feet, including the isolated area around boring SSB-12, where mobile DNAPL was recently observed during a short-term field pilot test. Under this RA, the focused treatment area would be thermally treated using ERH instead of steam injection. An estimated 473,700 pounds of DNAPL is estimated to occur within this focused treatment area, of which an estimated 236,800 pounds would be the volatile MCB component of the DNAPL and potentially subject to thermal remediation (although only a portion of this estimated mass would be recovered by ERH). ERH is a volatilization technology and would exclusively remove the MCB component of the DNAPL, leaving the DDT component in-situ. Montrose submitted technical memorandums identifying the conceptual approach for ERH to EPA on August 7 and 22, 2008 (Earth Tech, 2008e and 2008f).

Pilot Test:

While no ERH pilot test has been conducted at the Site, the relatively small size of the focused treatment area does not readily lend itself to implementation of a pilot (a pilot test would cover approximately 50% of the focused treatment area). Therefore, no pilot test would be conducted for this focused treatment area RA.

ERH Electrodes and Multiphase Extraction Wells:

A total of 87 ERH electrodes would be installed throughout the focused treatment area on a 21-foot spacing and in an offset linear pattern (21-foot equilateral triangles). An additional 15 ERH electrodes and 9 multiphase extraction wells would be required to treat the SSB-12 area. Each row of ERH electrodes would extend to or slightly beyond the edge of the focused treatment area as shown **Figure 5.25**. As shown in this figure, a total of 57 multiphase extraction wells are also spaced in an offset linear pattern but on a 27-foot spacing. Because the perimeter of the focused treatment area is still within the

DNAPL-impacted area, the outer wells of the pattern are extraction wells, intended to recover volatilized contaminants which may migrate away from the source area. Therefore, multiphase extraction wells are positioned around the perimeter of the focused treatment area (even beyond the estimated extent of mobile DNAPL) to recover volatilized contaminants along the edge of the thermal treatment area.

A conceptual ERH electrode construction diagram is provided as **Figure 5.26** and is based on the ET-DSP™ technology offered by McMillan-McGee. Each location would be constructed using three stacked 10-foot electrodes positioned at approximately 58 to 68, 75 to 85, and 92 to 102 feet bgs. The electrodes are capable of heating approximately 3 to 4 feet above and below the electrode length, and therefore, the electrodes were vertically positioned 6 to 8 feet apart. The multiphase extraction wells would be constructed as previously specified in Section 5.1.7 (screened from 45 to 105 feet bgs).

Hot Floor:

Because ERH relies exclusively on volatilization, there is a reduced risk of downward mobilization relative to steam injection. Therefore, no hot floor is assumed for this ERH RA.

Treatment Volume:

The focused treatment area is 26,000 square feet, and the treatment depths for this ERH RA would be 60 to 105 feet bgs, consistent the saturated UBA. Therefore, the target treatment volume for this area would be 43,400 cubic yards within the saturated UBA, including the treatment area surrounding boring SSB-12.

Energy Requirements:

The energy requirement for this ERH RA was estimated assuming a unit requirement of 200 kilowatt-hours per cubic yard as recommended by McMillan-McGee. Given the treatment volume of the saturated UBA (43,400 cubic yards), the total energy requirement for the saturated UBA is 8,680 megawatt-hours, including the treatment area surrounding SSB-12. The combined carbon footprint of SVE in the unsaturated zone and ERH in the saturated UBA over a focused treatment area is estimated to generate approximately 14 million pounds of carbon dioxide, requiring approximately 88,500 trees to offset the carbon dioxide production (Table 5.1 and Appendix H).

Operations Duration:

The total RA duration would be approximately 4 years including design, construction, operation and maintenance, verification, and abandonment. The duration of the heating portion only is estimated to be 12 months. Once target temperatures are achieved throughout the DNAPL-impacted zone, ERH operations would be terminated and verification borings would be drilled and samples collected to verify the performance of the remedy.

SVE and Ex-Situ Vapor Treatment:

Heated soil vapors would be extracted from the multiphase extraction wells for on-Site treatment. Approximately 750 scfm of soil vapors would be extracted using two liquid-ring vacuum blowers and cooled to condense moisture before being delivered to the vapor treatment system. Three soil vapor treatment process options were evaluated in Section 4.8, although a steam regenerable carbon/resin system is particularly applicable to this RA. A process flow diagram of the conceptual ERH remedial system is provided as **Figure 5.27**.

Ex-Situ Groundwater Treatment and Disposal:

Approximately 75 gpm of groundwater would be extracted from the multiphase wells for on-Site treatment. As described in Section 4.7, groundwater would be treated by a combination of LGAC to remove MCB and other VOCs by adsorption and HiPOx™ to destroy pCBSA by oxidation. Re-injection of the treated water is not fundamental to the ERH remedy and may serve to cool the subsurface. For this reason, treated groundwater would be transferred to the Groundwater Remedy Treatment System for subsequent re-injection into the BFS and Gage Aquifers (which was a process option specified in Section 4.9).

DNAPL Disposal:

As specified in Section 4.9, all recovered DNAPL would be disposed off-Site every 90 days or less.

Temperature Monitoring Points:

Approximately 12 temperature monitoring points would be installed throughout the focused treatment area to monitor subsurface heating both laterally and vertically. At each temperature monitoring point, thermocouples would be positioned every 5 vertical feet from approximately 25 to 115 feet bgs.

5.1.8 Remedial Alternative 6b – ERH, Entire DNAPL-Impacted Area without Hot Floor

This RA includes the following four remedial technologies and process options:

Containment

Hydraulic containment would be implemented as described in Section 5.1.1 and would be required for an estimated duration of approximately 3,100 to 4,200 years.

Institutional Controls

Institutional controls would be implemented as described in Section 5.1.2.

SVE (unsaturated zone)

SVE would be implemented in the unsaturated zone as described in Section 5.1.3. However, SVE within the unsaturated UBA is additionally a component of an ERH RA and used to recover volatilized VOCs from the underlying saturated UBA. Depending on depth, some of the SVE wells are used for both purposes. SVE from the PVS (25 to 45 feet bgs) remains the same as previously described in Section 5.1.3. However, the multiphase extraction wells used for a thermal remedy would be screened up to 45 feet bgs in the unsaturated zone, and therefore, SVE over the unsaturated UBA from 45 to 60 feet bgs is combined with the ERH remedy as indicated below. Under this ERH RA, installation of separate SVE wells within the unsaturated UBA, between 45 and 60 feet bgs, will not be required. Therefore, the cost of the SVE remedial component for this ERH RA is reduced.

ERH, Entire DNAPL-Impacted Area without Hot Floor

ERH would be implemented within the saturated UBA over the entire DNAPL-impacted area to thermally treat both residual and mobile DNAPL. ERH would be implemented in the same manner as for the focused treatment area, except that treatment would apply to the entire 160,000 square foot DNAPL-impacted area where an estimated 796,100 pounds of DNAPL are estimated to occur. Assuming that the MCB represents 50% of the DNAPL mass, an estimated 398,000 pounds of MCB is present at the Site and potentially subject to thermal remediation (although only a portion of this estimated mass would be recovered by ERH). The elements of the ERH conceptual design are summarized as follows:

Pilot Test:

A pilot test would be implemented in advance of full-scale ERH remedy throughout the entire DNAPL-impacted area. As indicated in Section 4.6.1, implementation of an ERH remedy throughout the entire DNAPL-impacted area at the Site would be the largest ERH project ever implemented in the United States and potentially the most complex given the Site lithology and unique nature of the DNAPL. An ERH pilot test has not been conducted at the Site to establish either the feasibility of the technology, or if feasible, initial design parameters. Therefore, under this RA, a pilot test would be conducted in advance of full-scale design. The pilot test would thermally treat an area of approximately 11,000 square feet and 18,300 cubic yards within the saturated UBA. Assuming the same well spacing as for the full-scale remedy, 30 ERH electrodes and 21 multiphase extraction wells would be installed within the saturated UBA to conduct the pilot. A conceptual well pattern for the pilot test is provided in **Figure 5.28**. The pilot test would be conducted for a period of approximately 6 months. Pilot-scale SVE system and groundwater treatment system would be employed during the test.

<u>ERH Electrodes and Multiphase Extraction Wells:</u>

ERH electrodes and multiphase extraction wells would be installed throughout the entire DNAPL-impacted area using the same well pattern and spacing indicated for the focused treatment area. A total of 456 ERH electrodes and 203 multiphase extraction wells would be installed as shown in **Figure 5.29**. The ERH electrode well pattern would overlay the estimated extent of the DNAPL.

<u>Hot Floor:</u>

Because ERH relies exclusively on volatilization, there is a reduced risk of downward mobilization relative to steam injection. Therefore, no hot floor is assumed for this ERH RA.

<u>Treatment Volume:</u>

The target treatment area is 160,000 square feet, and the treatment interval is from 60 to 105 feet bgs, consistent with the saturated UBA. Therefore, the target treatment volume for this RA would be 267,000 cubic yards within the saturated UBA, which if implemented, would be the largest ERH remedy ever to be undertaken.

<u>Energy Requirements:</u>

For the entire DNAPL-impacted area, a total of 53,400 megawatt-hours of electrical power would be required based on an assumed unit requirement of 200 kilowatt-hours per cubic yard (as recommended by McMillan-McGee). The combined carbon footprint of SVE in the unsaturated zone and ERH in the saturated UBA over the entire DNAPL-impacted area is estimated to generate approximately 58 million pounds of carbon dioxide, requiring an estimated 373,000 trees to offset the carbon dioxide production (Table 5.1 and Appendix H).

Operations Duration:

The total duration is estimated to be 7 years including pilot testing, design, construction, operation and maintenance, verification, and abandonment. The duration of the heating portion only is estimated to be 24 months.

SVE and Ex-Situ Vapor Treatment:

Heated soil vapors would be extracted from the multiphase phase for on-Site treatment. Approximately 2,000 scfm of soil vapors would be extracted using three liquid-ring vacuum blowers and cooled to condense moisture before being delivered to the vapor treatment system. A process flow diagram of the conceptual ERH remedial system is provided as **Figure 5.30**.

Ex-Situ Groundwater Treatment and Disposal:

Approximately 200 gpm of groundwater would be extracted from the multiphase wells for on-Site treatment by LGAC and HiPOx™. Treated groundwater would be transferred to the Groundwater Remedy Treatment System for re-injection into the BFS and Gage Aquifers.

DNAPL Disposal:

All recovered DNAPL would be disposed off-Site every 90 days or less.

Temperature Monitoring Points:

Approximately 70 temperature monitoring points would be installed throughout the DNAPL-impacted area to monitor subsurface heating both laterally and vertically.

5.2 SCREENING OF REMEDIAL ALTERNATIVES

The purpose of this section is to conduct an intermediate screening of the assembled RAs as prescribed in EPA guidance documentation for conducting feasibility studies under CERCLA (EPA, 1988). The RAs will be evaluated against the same three performance criteria used in Section 4.0: effectiveness, implementability, and relative cost. A brief description of these performance criteria is provided below. Following the intermediate screening evaluation, the surviving RAs will be retained for detailed evaluation in Section 6.0.

Effectiveness. Each RA is evaluated based on its relative effectiveness in meeting RAOs and protecting human health and the environment. RAs are evaluated and ranked as effective, moderately effective, minimally effective, potentially effective, or ineffective. This evaluation includes:

- The effectiveness of the RA in achieving the RAOs,
- The potential impacts to human health and the environment during the construction and implementation phase, and
- The reliability of the RA with respect to the contaminants and conditions at the Site.

Implementability. Each RA is evaluated based on the technical and administrative feasibility of implementing the specific technology. Technical feasibility refers to the applicability or compatibility of an RA to site conditions and contaminants of concern. Administrative feasibility refers to such issues as permitting and availability of equipment, among other factors. Each RA is evaluated and ranked as implementable, difficult to implement, or not implementable.

Cost. A limited cost evaluation is performed in this screening phase and is based primarily on engineering judgment and technology vendor experience. Capital costs, such as construction costs, and long-term monitoring or operation and maintenance costs are considered. Each RA is evaluated and ranked as very high, high, medium, low, or no cost.

5.2.1 REMEDIAL ALTERNATIVE 1 – NO ACTION

This RA includes two GRAs: (1) No Action for DNAPL in both the unsaturated and saturated zones, and (2) containment in the saturated zone as required by the Groundwater ROD.

Effectiveness. In combination with the remedies for soil and groundwater, the No Action RA would meet DNAPL RAOs in the long-term and be moderately effective in protecting human health and the environment. Containment of dissolved-phase contaminants is required by the remedy for groundwater, which effectively eliminates groundwater exposure pathways. Migration of dissolved-phase contaminants would be controlled through hydraulic extraction, and DNAPL mass is reduced over time through dissolution. Human exposure to contaminated groundwater at the Property would be restricted (and eliminated outside the TI Waiver Zone), and monitoring of groundwater conditions would be conducted to ensure that hydraulic containment is achieved. Access to the Site is already restricted and inspected/maintained on a routine basis, and the future remedy for soil would address exposure risks at surface. The Soil FS will address VOC migration at land surface. The No Action RA is by definition a reliable process with no adverse impacts.

Currently, DNAPL does not appear to be migrating substantially, nor is its impact increasing, and therefore, an accelerated DNAPL mass removal RA would not be required to protect human health and the environment in the short-term. Under the No Action RA, there is no potential to exacerbate the current distribution of DNAPL, which is not necessarily the case for more aggressive thermal remediation RAs. However, under the No Action RA, no DNAPL mass in the unsaturated zone would be reduced, and VOCs in the deeper PVS and unsaturated UBA would not be removed. ***Rank: Moderately Effective.***

Implementability. By definition, the No Action RA is highly implementable. ***Rank: Implementable.***

Cost. By definition, there is no cost associated with the No Action RA. The containment aspect of this RA would be implemented as part of the remedy for groundwater. ***Rank: No Cost.***

Retain for Detailed Analysis? As required by the NCP, this No Action RA is retained for detailed evaluation as a baseline for comparison with other RAs. ***Retain? Yes.***

5.2.2 REMEDIAL ALTERNATIVE 2 – INSTITUTIONAL CONTROLS

This RA includes two GRAs: (1) institutional controls, and (2) containment in the saturated zone as required by the Groundwater ROD.

Effectiveness. The effectiveness of this alternative is very similar to RA 1, with the addition of institutional controls. Under this RA, future use of the Property would be limited by a deed restriction, and access limitations to the Site would be implemented as a formal component of the remedy. This RA meets the DNAPL RAOs in the long-term (no short-term DNAPL mass or mobility reduction) and would be effective in reducing the potential for human exposure to contaminated soils, DNAPL, and groundwater. Human exposure to contaminants at surface is excluded from this evaluation and will be addressed by the Soil FS for the Site.

Institutional controls for DNAPL would be limited to DNAPL-impacted areas including the Montrose Property and potentially a small portion of the former Boeing Realty Corporation property to the north. The institutional controls RA is a reliable process with no adverse impacts to human health or the environment. The hydraulic containment component of the RA prevents migration of dissolved-phase contaminants through hydraulic extraction and reduces DNAPL mass over time by dissolution. The time required for hydraulic containment under this RA is the same as for the No Action RA. The Soil FS will address VOC migration at land surface. Currently, DNAPL does not appear to be migrating substantially, nor is its impact increasing, and therefore, an accelerated DNAPL mass removal RA would not be required to protect human health and the environment. Under RA 2, there is no potential to exacerbate the current distribution of DNAPL, which is not necessarily the case for more aggressive thermal remediation RAs. However, as under the No Action RA, no DNAPL mass in the unsaturated zone would be reduced, and VOCs in the deeper PVS and unsaturated UBA would not be removed.

The merits of a containment-based remedy for DNAPL-impacted sites have been recognized by EPA as indicated in Section 4.3. In a document entitled *The DNAPL Remediation Challenge: Is There a Case for Source Depletion* (EPA, 2003), EPA indicates that "*for large, complex sites, with fractured systems, and DNAPL at depth, costs for the source depletion strategy may not be justified, and containment may be the logical option*". The 2003 EPA study also recognized the potential limitations associated with DNAPL source depletion technologies, indicating that "*…the appropriateness of applying intensive and often costly remediation technologies for DNAPL extraction or destruction in the source zone, if such partial mass removal will not have a quantifiable and substantial impact on the duration and life-cycle costs of a containment remedy, such as pump-and-treat*". Containment is additionally a highly reliable process option for protecting human health and the environment. Unlike some of the more aggressive source zone remediation technologies, such as steam injection, there are no significant adverse impacts associated with containment that could result in the spreading of contamination. The 2003 EPA study recognized the potential adverse affects of source depletion. Specifically, the expert panel recognized the potential for thermal remediation to:

- Expand the source zone if trapped DNAPL is mobilized
- Change the composition and behavior of DNAPLs, making them more mobile or more toxic
- Selective removal of the more volatile constituents, leaving behind higher molecular weight components as residuals.

The expert panel from the 2003 EPA study established a decision process for evaluating the potential applicability of source zone depletion at a site as indicated in Section 4.3. Based on that decision process, source depletion is less needed at the Montrose Site, and none of the factors requiring source depletion are triggered by the conditions at the Montrose Site.

Despite technological advances, effective remediation of DNAPL-impacted source zones remains problematic, and many technical experts question the cost-benefit of aggressive source zone remediation technologies. In a 2000 paper (Freeze, 2000), the author advocated implementation of source containment due to the technical impracticability of removing sufficient DNAPL mass to reduce contaminant concentrations to cleanup standards. In a separate evaluation in 2006 (McGuire, et. al., 2006), the authors recognized that the "*…degree of uncertainty in the costs and benefits of applying source depletion technologies is currently at levels that discourage widespread use of the available source depletion technologies at DNAPL sites*". ***Rank: Moderately Effective.***

Implementability. There are no technical or administrative aspects that would limit the implementability of recording a deed restriction for the on-Property portion of the Site, where nearly all of the DNAPL occurs in the subsurface. However, a small portion of the DNAPL may be present below the adjacent property to the north (former Boeing Realty Corporation), and application of deed restrictions at the off-Property areas would require consent of the land owners. ***Rank: Implementable.***

Cost. The relative cost for this institutional controls RA is very low. There is only a minimal cost associated with implementation of a deed restriction and other pre-existing institutional controls. ***Rank: Low.***

Retain for Detailed Analysis? This institutional controls RA would be effective in protecting human health by controlling the contaminant exposure pathways and is the lowest cost RA, other than the No Action alternative. The hydraulic containment component of this RA will prevent migration of dissolved-phase contaminants and will reduce DNAPL mass in the long-term by dissolution. This RA is retained for detailed evaluation. ***Retain? Yes.***

5.2.3 REMEDIAL ALTERNATIVE 3 – SVE IN THE UNSATURATED ZONE

This RA includes three GRAs: (1) SVE in the unsaturated zone, (2) institutional controls, and (3) containment in the saturated zone as required by the Groundwater ROD.

Effectiveness. This RA meets DNAPL RAOs in the long-term and would be highly effective in reducing DNAPL mass and mobility in permeable unsaturated soils. Under this RA, the mass and mobility of VOCs and DNAPL in the unsaturated zone, within the PVS and unsaturated UBA, would be effectively reduced by SVE. The future risk to groundwater from contaminant leaching would also be significantly reduced by SVE. The effectiveness of SVE to remove VOCs from the unsaturated zone was demonstrated by field pilot testing in 2003 as summarized in Section 2.6.4. The MCB component of the DNAPL would be volatilized and extracted for ex-situ vapor treatment. The DDT component of the DNAPL would be left in place, where it poses no risk to human health and the environment due to a lack of exposure pathways. DDT is not volatile, relatively insoluble in groundwater, and relatively immobile in deeper soils (no migration risk). The Soil FS will address VOC migration at land surface.

This RA would additionally include the protectiveness offered by institutional controls and long-term hydraulic containment as specified for RA 2. The institutional controls and groundwater containment aspects of the RA would be effective in preventing human exposure to contaminated soils, DNAPL, and groundwater. The hydraulic containment component of the RA prevents migration of dissolved-phase contaminants through hydraulic extraction and slowly reduces DNAPL mass over time by dissolution. The containment timeframe estimates assume that none of the unsaturated zone MCB mass leaches to groundwater, and therefore, the estimated duration for hydraulic containment under this RA is the same as for the No Action RA (approximately 4,900 years).

Currently, DNAPL does not appear to be migrating substantially, nor is its impact increasing, and therefore, an accelerated DNAPL mass removal RA would not be required to protect human health and the environment in the short-term. Under RA 3, there is no potential to exacerbate the current distribution of DNAPL, which is not necessarily the case for more aggressive thermal remediation RAs.

However, SVE would not be implemented within the PD soils from approximately 4 to 25 feet bgs due to the low permeability of these soils. During field pilot testing in 2003, SVE was found to be significantly less effective for removal of VOCs from the low permeability PD soils. VOCs present in the PD would remain in place as a potential source to shallow soil gas. Human exposure pathways at surface and in shallow soils are being addressed by the Soil FS for the Site (in press), and the future remedy for soil is expected to be protective of human health and the environment. ***Rank: Highly Effective (in permeable unsaturated soils).***

Implementability. This RA is implementable. There are no technical or administrative aspects that would limit the implementability of this RA. SVE is a widely used technology for remediating VOCs in permeable soils, and equipment required to implement the RA is readily available. Highly skilled operators are not required for this RA, and there are a large number of contractors available to provide SVE remediation services. The SVE aspects of this RA would have to meet ARARs for air emissions. ***Rank: Implementable.***

Cost. The relative cost of this SVE RA is low to medium. Installation of approximately 23 extraction wells in the unsaturated zone and ex-situ soil vapor treatment would be required under this RA. ***Rank: Low to Medium.***

Retain for Detailed Analysis? The SVE component of this RA would reduce the mass of VOCs and DNAPL in the unsaturated zone, thereby increasing the protectiveness of groundwater and controlling VOC migration in soil gas. Field pilot testing has demonstrated the potential effectiveness of SVE to initially remove a relatively high mass of vapor-phase VOCs from permeable unsaturated soils. The institutional controls component of the RA would protect human health by controlling the contaminant exposure pathways. The hydraulic containment component of this RA will prevent migration of dissolved-phase contaminants in the saturated zone and will reduce DNAPL mass in the long-term by dissolution. This RA is retained for detailed evaluation. ***Retain? Yes.***

5.2.4 REMEDIAL ALTERNATIVE 4 – HYDRAULIC DISPLACEMENT WITH UNTREATED WATER INJECTION

This RA includes four GRAs: (1) hydraulic displacement with untreated water re-injection in the saturated UBA, (2) SVE in the unsaturated zone, (3) institutional controls, and (4) containment in the saturated zone as required by the Groundwater ROD.

Effectiveness. Hydraulic displacement would remove DNAPL in saturations exceeding residual, and both the mass and mobility of DNAPL in the saturated UBA would be reduced under this RA, thereby meeting DNAPL RAOs. Simultaneous groundwater extraction and re-injection would displace mobile DNAPL towards recovery wells for extraction. This process was shown to be effective during DNAPL extraction testing in 2004/2005 where DNAPL was recovered at a rate up to 5.6 gallons per day from a single well even though the testing was conducted without the benefit of increased hydraulic gradients from groundwater re-injection (as proposed by this RA). During extraction testing, the rate of DNAPL recovery increased with increasing hydraulic gradients. Since re-injection of groundwater will increase hydraulic gradients over what was field pilot tested, an increased rate of DNAPL recovery, above those observed during testing, may be realized by this hydraulic displacement RA.

Although some DNAPLs are not readily mobilized for extraction by hydraulic displacement (i.e., DNAPLs exhibiting high density, high viscosity, and/or high interfacial tension), field pilot testing has demonstrated that the Montrose DNAPL can be effectively recovered by this technology. The Montrose DNAPL is considered to be moderately mobile, as indicated in Section 2.1.2. Although the DNAPL density (1.25 g/cc) is 25% higher than that of water (1 g/cc), this density difference is not so high as to preclude the use of this technology. Mobile DNAPL has been successfully recovered through active hydraulic extraction from all pilot test wells located within the estimated mobile DNAPL footprint, and the rate of DNAPL recovery increases with increasing hydraulic gradients. Any concerns related to the potential effectiveness of hydraulic displacement to mobilize the Montrose DNAPL (CH2M Hill, 2007) have been definitively addressed through field pilot testing (Section 2.6.3) and computer modeling (Section 2.6.4)..

Hydraulic displacement under RA 4 would remove the most DNAPL-phase DDT from the subsurface of all RAs under consideration. The thermal remediation technologies preferentially remove the volatile or MCB component of the DNAPL, leaving the DDT component behind. However, hydraulic displacement works within the existing DNAPL architecture to remove mobile DNAPL composed of both MCB and DDT. Approximately 88,700 pounds of DDT would be removed by hydraulic displacement under RA 4, assuming 80% mass removal efficiency, which would otherwise be left in-situ by the thermal remediation RAs.

Higher saturations of DNAPL (i.e., highest mass) are the most mobile and would be the easiest to recover by hydraulic displacement. DNAPL occurring just slightly above residual levels would be the least mobile, but it poses a reduced risk of mobilization laterally or vertically to the BFS. Unlike steam injection, hydraulic displacement depletes DNAPL saturations, making the remaining DNAPL less and less mobile over time. By comparison, steam injection tends to concentrate DNAPL at the steam front, increasing the DNAPL saturation, mobility, and potential for vertical migration. Although hydraulic displacement relies on fluid flow through porous and permeable saturated soils, steam injection is equally reliant on these site conditions. While hydraulic displacement works within the existing DNAPL architecture, thermal remediation changes the DNAPL architecture, increasing the importance of understanding the DNAPL distribution and movement to prevent uncontrolled migration of contaminants at the Site. Additionally, hydraulic displacement removes more DNAPL-phase DDT than either steam injection or ERH, which preferentially remove the MCB component of the DNAPL, leaving the DDT component behind.

As is true for all RAs under consideration, residual saturations of DNAPL would be left in place following the hydraulic displacement component of the RA (e.g., such as the 18.9% residual DNAPL saturation measured in one UBA soil core [Section 2.1.2]). However, residual DNAPL is relatively immobile in the environment and poses little or no risk to the underlying BFS other than as a continuing source of dissolved-phase MCB, which is effectively addressed by hydraulic containment.

Re-injection of untreated groundwater will be effective in displacing DNAPL, and removal of the dissolved-phase constituents by ex-situ treatment is not required for this hydraulic displacement RA. Contaminant mass reduction under RA 4 occurs by removal of the liquid-phase DNAPL and is not dependent on removal of the dissolved-phase mass, which is very small in comparison. Other than DNAPL separation and solids filtration, groundwater would not be treated ex-situ prior to re-injection into the UBA.

Discontinuous silt layers have the potential to allow some downward migration during hydraulic displacement; however, the risk of this migration can be significantly reduced through a higher well density. As such, an alternate well spacing of 25-feet between extraction wells is being evaluated for this RA. The potential for downward mobilization was evaluated by H+A and Intera using preliminary modeling, and model results indicated there was no downward mobilization past the basal silty sand member of the UBA during or after hydraulic displacement assuming DNAPL pool heights up to 8 feet (H+A, 2009b). The preliminary modeling also indicated that DNAPL would be effectively mobilized to the extraction wells at spacings up to 120 feet, and therefore, the 50-foot well spacing identified in Section 5.1.4 is expected to be effective.

The SVE component of the RA would reduce VOC and DNAPL mass/mobility in the unsaturated zone and would control VOC migration in soil gas. The institutional controls component would protect human health by controlling contaminant exposure pathways. The hydraulic containment component of this RA will prevent migration of dissolved-phase contaminants and reduce the mass of residual DNAPL in the long-term. Assuming a 80% mobile MCB mass removal efficiency, this RA is expected to reduce the duration of long-term hydraulic containment from approximately 4,900 to 4,700 years. ***Rank: Effective for mobile DNAPL.***

Implementability. This RA is implementable. Extraction wells can be installed using standard drilling methods and equipment. Standard separation techniques can be used to separate the Montrose DNAPL from groundwater. Specialized field equipment or contractors are not required for this RA. Precipitate fouling of the extraction pumps/piping was observed during the extraction pilot test, but the fouling effects could be abated during operations through routine maintenance. Administratively, the re-injection limits specified in the groundwater ROD would need to be waived in order to implement the RA (which was approved for the 2004/2005 extraction test). ***Rank: Implementable.***

Cost. The relative cost of this hydraulic displacement RA is medium. Installation of approximately 18 multiphase extraction and 23 injection wells (50-foot well spacing) or 32 multiphase extraction and 37 injection wells (25-foot well spacing) would be required under this RA, including the isolated area surrounding boring SSB-12. Recovered DNAPL would be transported off-Site for disposal, but extracted groundwater would only be filtered prior to re-injection (no treatment for VOCs or pCBSA). Re-injection of untreated groundwater substantially reduces the cost of this RA. This RA would additionally include SVE within the unsaturated zone. ***Rank: Medium.***

Retain for Detailed Analysis? This RA would reduce DNAPL mass and significantly reduce DNAPL mobility in the saturated UBA. Field pilot testing has demonstrated the potential effectiveness of hydraulic displacement to initially remove a relatively high volume of mobile DNAPL from the saturated UBA. The SVE component of this RA would reduce the mass of VOCs and DNAPL in the unsaturated zone, thereby increasing the protectiveness to groundwater and controlling VOC migration in soil gas. The institutional controls component of the RA would protect human health by controlling the contaminant exposure pathways. The hydraulic containment component of this RA will prevent migration of dissolved-phase contaminants in the saturated zone and will reduce DNAPL mass in the long-term by dissolution. This RA is retained for detailed evaluation. ***Retain? Yes.***

5.2.5 REMEDIAL ALTERNATIVE 5A – STEAM INJECTION OVER FOCUSED TREATMENT AREA

This RA includes four GRAs: (1) steam injection over a focused treatment area, (2) SVE in the unsaturated zone, (3) institutional controls, and (4) containment in the saturated zone as required by the Groundwater ROD.

Effectiveness. This RA may be effective in reducing the DNAPL mass and mobility within a focused treatment area, consistent with the estimated extent of mobile DNAPL at the Property. Steam injection has the potential to reduce DNAPL mass, both residual and mobile, within the focused treatment area either through MCB volatilization or DNAPL flushing. Although the focused treatment area is only 16% of the entire DNAPL-impacted area, it is estimated to contain 100% of the mobile DNAPL and approximately 60% of the total DNAPL mass in the saturated zone. DNAPL occurs in the highest concentrations within the focused treatment area covering approximately 22,900 square feet of the CPA and a 3,100 square foot area surrounding boring SSB-12 (located east/southeast of the CPA). Outside of the focused treatment area, DNAPL occurs in lower concentrations that are believed to be relatively immobile in the environment (i.e. residual DNAPL). Based on a review of case study sites, the size of the focused treatment area is consistent with the average treatment area applied at other thermal remediation sites.

However, steam injection has not been pilot tested at the Site, and the potential effectiveness of this RA is highly uncertain. As indicated in Section 4.6.3, there are numerous technical challenges that could reduce the effectiveness of this RA including preferential steam flow, steam over-ride, downward mobilization, and the inability to recover volatilized MCB, among others. The saturated UBA is highly layered, with alternating layers of permeable sand layers and low permeability silt layers, and steam injection is dependent on permeable soils for delivery of steam to the treatment area. Steam will preferentially flow through the sand layers, and heating of the less permeable soils may be problematic and reliant on thermal heat conduction from adjacent sand layers. In a 2006 evaluation (Basel, 2006), the author indicated that "*geologic conditions more favorable for steam injection than other geologies include soil with limited heterogeneities and moderate permeability (10^{-3} cm/s or greater)*".

For this reason, steam injection was not assembled into a formal RA at the Del Amo Superfund Site where the lithology of one of the NAPL-impacted areas is similar to the Montrose Site (URS, 2008). The rationale for excluding a formal steam injection alternative at the Del Amo Site was that the low permeability and heterogeneous nature of the aquitard soils were not well suited for application of steam injection. Although ERH was assembled into a formal RA at the Del Amo Site, that site should not be a precedent for the Montrose Site. The co-boiling point of benzene (69°C) is significantly lower than the Montrose DNAPL (96°C), and it is noted that Shell objects to selection of a thermal remedy for the Del Amo Superfund Site and has appealed to the Remedy Review Board.

The layered nature of the UBA will additionally limit the ability to recover volatilized MCB because where sand layers are thick, steam has the potential to flow along the top of the sand layer and bypass, to some extent, DNAPL accumulated at the bottom of the sand layer. If volatilized MCB vapors are not effectively recovered, they have the potential to condense, resulting in MCB accumulation in another part of the saturated UBA.

Steam injection has never been applied to a DNAPL site where either MCB or DDT was a primary component of the DNAPL. The relatively high co-boiling point of the Montrose DNAPL (96°C) and low vapor pressure of MCB (12 mm Hg at 20°C) would likely result in reduced mass removal efficiencies as compared with some other VOCs with lower co-boiling points, such as TCE (73°C). The effectiveness of steam injection to thermally treat soils impacted with an MCB DNAPL has never been demonstrated at either pilot or full-scale. Under steam injection, there is the potential for mobilization of liquid-phase DDT if soils are heated to temperatures exceeding the melting point of DDT (108.5°C at 1 atmosphere pressure).

Steam injection will mobilize DNAPL via flushing and concentrate the DNAPL at the steam front. Mobilized DNAPL that is not effectively recovered has the potential to migrate laterally and/or downward through discontinuous silt layers. Uncontrolled steam distribution could result in spreading of the contamination within the saturated zone, potentially including the adjacent industrial building located on the former Boeing Realty Corporation property. This type of contaminant spreading, if it were to occur, would not be protective of human health and the environment, would not meet the DNAPL RAOs, and would reduce the effectiveness of this RA.

Additionally, EPA has recommended a 60-foot spacing between extraction and injection wells, which is larger than either of the well spacings considered for hydraulic displacement in RA 4 (25 to 50 feet). Therefore, DNAPL flushed laterally under this steam injection RA has an increased potential of encountering a silt discontinuity between well pairs, as compared with the hydraulic displacement RAs. Additionally, a large percentage of the steam will condense in the subsurface. The condensed steam will become contaminated as it contacts DNAPL and has the potential to migrate vertically downward as well. While the mass of dissolved MCB in condensed steam would be substantially lower than DNAPL, it still has the potential to impact the BFS in concentrations significantly higher than what is currently present in the underlying aquifer unit. Downward mobilization of DNAPL could exacerbate, rather than mitigate, the environmental impacts existing at the Site.

For the above reasons, implementation of a hot floor is required to reduce the potential for steam condensate and DNAPL to migrate vertically downward into the BFS. However, hot floors are very infrequently implemented, and the effectiveness of a steam injection hot floor in reducing downward mobilization has not been demonstrated at a comparable site. In the limited number of cases where a hot floor was implemented, ERH or TCH was primarily used to heat the hydrologic layer underlying the DNAPL-impacted zone. Although steam was injected into an underlying aquifer unit at the SCE Site in Visalia, California, the primary reason was to prevent the upward flow of cool groundwater into the thermal treatment zone (not to prevent downward flow of DNAPL). For these reasons, implementation of a hot floor in the BFS may not be a reliable method for preventing downward migration during a steam injection remedy. Furthermore, drilling the hot floor wells through DNAPL-impacted soils increases the risk of downward migration to occur during drilling or as a result of drilling if efforts to isolate the overlying UBA are not successful. The effectiveness of the isolation efforts during drilling are not guaranteed and would not effectively isolate overlying soils if the conductor were set in a sand layer. In a 2006 evaluation (Basel, 2006), the author identified some of the technical challenges associated with steam injection as "*control of steam front growth to prevent undesired conditions such as venting up to the ground surface, downward flow, overriding of target constituents, or unintended constituent migration*", among other factors.

This RA would additionally include the effectiveness offered by the components of RA 3. The VOC/DNAPL mass in the unsaturated zone would be significantly reduced by SVE, and VOC migration in soil gas would be controlled. If successful, this RA would be effective in protecting human health and the environment by limiting exposure to DNAPL-impacted soils and groundwater. Migration of the dissolved contaminant plume in groundwater would be controlled through hydraulic containment. Assuming an 80% MCB mass removal efficiency in the focused treatment area, the duration required for hydraulic containment in the saturated zone would be reduced from approximately 4,900 to 4,400 years; (or longer, if thermal remediation is unable to achieve the assumed mass reductions). ***Rank: Potentially Effective (but highly uncertain).***

Implementability. This steam injection RA would be difficult to implement. A significant amount of complex above- and below-ground infrastructure would be required to generate and deliver steam throughout the focused treatment area. A large number of wells (steam injection, multiphase extraction, and temperature monitoring) would be required and would generate a significant amount of waste. This RA additionally includes implementation of SVE in the unsaturated zone, ex-situ vapor treatment, and ex-situ groundwater treatment. Unlike RA 4, where the groundwater is re-injected into the UBA to enhance hydraulic gradients, the groundwater under this RA would require ex-situ treatment for re-injection into the BFS and Gage through the Groundwater Remedy Treatment System. Re-injection of the treated groundwater into the UBA would potentially cool the subsurface, reducing the effectiveness of the thermal remedy. The re-injection flow requirement of the DNAPL remedy would need to be considered during design of the Groundwater Remedy Treatment System. Implementation of a hot floor in the underlying BFS would additionally be required to reduce the risks associated with downward migration of DNAPL and steam condensate. Installation of the hot floor wells would require more sophisticated and more costly drilling methods (such as mud-rotary) in an effort to isolate the overlying DNAPL-impacted soils during drilling. Extreme care would be required to ensure that DNAPL did not migrate downward into the BFS during installation of the hot floor wells. This RA would require highly skilled operators and a high level of maintenance.

Steam injection is an energy-intensive remedial technology, and the amount of energy required to heat the focused treatment area would be large. The resulting carbon footprint is similarly large (approximately 46 million pounds of greenhouse gases) and is not in accordance with EPA green remediation initiatives or the California Global Warming Solutions Act of 2006, which are TBCs for this FS.

Another factor increasing the difficulty of implementing this RA is a lack of steam vendors. Only two thermal remediation vendors, TerraTherm and Praxis Environmental, continue to pursue steam injection for site remediation. Praxis Environmental is a small, independent one-person firm with insufficient resources to implement a project of this size. A lack of adequate commercial steam injection vendors limits the implementability of this RA.

Montrose consulted with a relatively large number of technical experts, many of whom have previously participated in EPA advisory panels, in reviewing steam injection as a candidate remedial technology. The technical experts unanimously indicated that steam injection is not being implemented as frequently as other candidate thermal technologies (ERH and ISTD). Currently, there are only four active steam injection sites in the United States: (1) the Pacific Wood Treating Site in Port of Ridgefield, Washington, (2) the Savannah River M-Area Settling Basin Site in Aiken, South Carolina, (3) the Williams Air Force Base OU2 Site in Mesa, Arizona, and (4) the Northrop (formerly TRW) Site in Danville, Pennsylvania. However, none of these sites are comparable to the Montrose Site for the reasons identified in Section 5.2.6 and Appendix L. ***Rank: Difficult to Implement.***

Cost. The relative cost of this focused treatment area steam injection RA is high. Approximately 40,000 cubic yards of saturated UBA soils would be thermally heated by this RA. The resulting energy requirement for this RA is high at between 163,000 and 244,000 MCF of natural gas (for the saturated UBA), even though it addresses a focused treatment area. Implementation of a hot floor in the underlying BFS (upper 10 feet) substantially increases the cost of this RA and would increase the thermal treatment volume by approximately 22%. Additionally, the hot floor wells are costly to install (approximately 3 times that of UBA wells drilled using standard techniques) since conductor casings are required to isolate the DNAPL-impacted UBA during drilling. Given that the potential effectiveness of the hot floor is uncertain at such a complex site, the large financial investment would be wasted if only portions of the hot floor were adequately heated. Combined with SVE in the unsaturated zone, ex-situ vapor treatment, and ex-situ groundwater treatment, the relative cost of this RA is high.

Further, climate change regulation is expected to increase the costs of both natural gas and electricity because upstream suppliers of these commodities are expected to be regulated at both the State and Federal level. In other words, as a price is placed on carbon emissions, whether directly via a carbon tax or, more likely, indirectly via State and/or Federal cap-and-trade regimes, the cost of carbon-intensive forms of energy (e.g., natural gas and non-renewably generated electricity) will increase. Such increased costs would add additional cost to this RA. ***Rank: High.***

Retain for Detailed Analysis? The steam injection component of this RA has not been field pilot tested, and the potential effectiveness of steam injection at the Site is highly uncertain. Steam injection may not be effective in treating the low permeability and heterogeneous saturated UBA. As indicated in Section 2.6.6, 2-dimensional bench-scale testing suggests that only 64% of the DNAPL-phase MCB may be recovered by steam injection (University of Toronto, 2009). Steam would be expected to flow preferentially along the higher permeability layers and may not effectively heat the lower permeability layers. There is also an increased potential for downward mobilization associated with steam injection due to the build-up of DNAPL at the steam front and generation of steam condensate. A hot floor in the underlying BFS would be required to attempt to reduce the potential for downward mobilization if steam injection were implemented at the Site, and the potential effectiveness of a steam injection hot floor has not previously been demonstrated at a comparable site.

Steam injection is infrequently implemented, in comparison with other thermal technologies and is no longer being pursued as a commercial technology by some vendors. Only one technology vendor has sufficient resources to potentially implement a steam injection RA of this size. Additionally, a higher amount of greenhouse gases would be generated by this steam injection RA as compared with the equivalent ERH RA (RA 6a). Furthermore, Montrose has serious reservations about implementing a steam injection remedy, which is prone to displacement and spreading of contaminants, adjacent to the industrial building located at the former Boeing Realty Corporation property. Implementation of a steam injection remedy adjacent to that operating business would include a higher risk of contaminant migration and human exposure.

It is noted that EPA does not necessarily agree with this evaluation of steam injection. In spite of the disadvantages, EPA has expressed interest in the candidacy of steam injection as a RA for the Montrose Site. Accordingly, this steam injection RA is retained for detailed evaluation as requested by EPA. ***Retain? Yes.***

5.2.6 REMEDIAL ALTERNATIVE 5B – STEAM INJECTION OVER ENTIRE DNAPL-IMPACTED AREA

This RA includes four GRAs: (1) steam injection over the entire DNAPL-impacted area, (2) SVE in the unsaturated zone, (3) institutional controls, and (4) containment in the saturated zone as required by the Groundwater ROD.

Effectiveness. This RA along with RA 6B reflects the highest level of DNAPL source removal action considered in the FS. The entire DNAPL-impacted area would be thermally treated under this RA including both mobile and residual DNAPL within the source areas at the CPA and east of the CPA where the DNAPL generally thins and occurs in lower saturations. This RA (and RA 6b) has the potential to remove the most DNAPL mass, although, at a significantly higher cost, it would not reduce the DNAPL mobility over RAs 4 and 5a, nor would it meaningfully reduce required timeframes for groundwater containment. Steam would be injected into between 48 and 61 wells to heat the saturated UBA (depending on the well pattern used), volatilizing MCB for removal in soil vapor and displacing liquid-phase DNAPL for recovery at extraction wells. This RA's effectiveness is similar to that of RA 5a, except that it would additionally remove DNAPL mass from outside the focused treatment area where 40% of the DNAPL mass is estimated to occur and is already at residual saturations (and therefore immobile in the environment). Over the large treatment area of this RA, the effectiveness of steam injection may be reduced due to non-uniform heating, formation of cold spots, and an inability to reach and maintain target temperatures.

However, as previously indicated in Section 4.6.3, if implemented, this RA would be one of the four largest thermal remediation projects ever conducted in the United States. There are no comparable sites (to the Montrose Site) where steam injection has been implemented. The SCE Site in Visalia, California and the Savannah River Site in Aiken, South Carolina have been cited as being comparable to the Montrose Site. However, there are many critical differences that detract from the comparability of these sites to Montrose as follows:

> Contaminant: The primary contaminants at the SCE Visalia site were creosote (with pentachlorophenol) and diesel fuel. SCE reported that the creosote became an LNAPL at temperatures greater than 50°C, and therefore, the physical properties of the primary contaminants are fundamentally different from the Montrose Site, with no significant risk of downward migration.
>
> Lithology: At the SCE Visalia site, steam was injected into the Intermediate Aquifer from 80 to 100 feet bgs, which was described as a medium to coarse-grained sand with some gravel. At the Savannah River Site, steam was injected into the M-Area Aquifer, which had a saturated sand thickness of 25 to 30 feet. The lithology at both of these sites is far more suited to steam injection than the layered and highly heterogeneous lithology of the saturated UBA at the Montrose Site (sequences of thin sands interbedded with layers of silt). The lithology of the DNAPL-impacted UBA at the Montrose Site is fundamentally different from most other steam injection applications (within the saturated zone).
>
> Steam Injection Rate: At the SCE Visalia site, steam was injected at a combined rate up to 200,000 lbs/hr into 11 wells (average of 15,000 to 20,000 lbs/hr per well). At the Montrose Site, the combined full-scale steam injection rate was reduced from 60,000 to 40,000 lbs/hr following EPA comments on preliminary remediation cost estimates (into a minimum of 48 wells). Lower steam injection rates may result in reduced MCB mass removal efficiencies.

Pore Volumes/Energy Consumption: SCE has reported that "approximately 8" pore volumes of steam were flushed through the Intermediate Aquifer during the steam remedy. At the Savannah River Site, more than 2.5 times more steam was required than originally expected based on computer modeling. Steam was injected into the primary sand aquifer (M-Area Aquifer) over a period of 3.3 years to thermally remediate a DNAPL composed primarily of PCE and TCE (co-boiling point of <88°C). Had steam injection been terminated at the target energy demand, less than 60% of the DNAPL removed to date would have been recovered from the site. The mass removal efficiency would, of course, be less than 60%.

By comparison, the number of steam pore volumes assumed for the Montrose Site was reduced to between 2 and 3 following EPA comments on preliminary remediation cost estimates. However, lower energy and steam delivery to the saturated UBA will result in lower reductions in DNAPL mass/volume and reduced ability to effectively heat the treatment area. If up to 8 pore volumes of steam flushing are required at the Montrose Site, then the steam remedy costs assuming only 2 to 3 pore volumes of flushing would be greatly understated. The Montrose Site, given the heterogeneous UBA and complicated DNAPL architecture, may require more pore volumes of steam flushing that the SCE Visalia Site, not less.

Hot Floor: At the Savannah River Site, the M-Area Aquifer is underlain by a low permeability clay (the Green Clay), which serves as a capillary barrier preventing further downward migration of the PCE DNAPL. As a result, a hot floor was not implemented or required at the Savannah River Site. Although steam was injected into the Deep Aquifer at the SCE Visalia site, the purpose was to prevent continued influx of cool groundwater into the thermal treatment zone and not to mitigate the potential for downward migration. Furthermore, only a small portion of the underlying Deep Aquifer at the SCE Visalia site was heated using just 3 steam injection wells. At the Montrose Site, a 20 to 25 foot thick sand aquifer (the BFS) underlies the DNAPL-impacted UBA and would require heating over the entire thermal treatment area.

DNAPL Displacement: CH2M Hill has indicated that displacement of liquid-phase DNAPL is an advantage of steam injection over other thermal technologies (CH2M Hill, 2007). However, at the Savannah River Site, less than 0.1% of the DNAPL mass was recovered in liquid-phase; greater than 99.9% of the mass recovered was in the vapor-phase. Therefore, this advantage appears to be overstated.

The former Williams Air Force Base has also been identified as a site where steam injection is being applied over a thick saturated zone (CH2M Hill, 2007), but this site should not be considered a precedent for the Montrose Site for the following reasons:

Williams Air Force Base: Steam is being injected as part of a thermal enhanced extraction (TEE) pilot project in Operable Unit (OU) 2. However, the contaminant type is an LNAPL composed of jet fuel (JP-4) and aviation gasoline, which is fundamentally different from the Montrose DNAPL. Although the LNAPL has been smeared over a thick interval due to a water table that has risen approximately 40 feet in the last ten years, a portion of the LNAPL will occur at the water table, and there is no risk of downward migration (no hot floor is required). The primary toxic constituent of the LNAPL is benzene, which is far more volatile than MCB (81 mm Hg and 12 mm Hg at 1 atmosphere, respectively) and boils at a significantly lower temperature than MCB (80°C and 132°C respectively).

The pilot project is targeting a soil volume of approximately 46,000 cubic yards, which is similar to the volume considered by RA 5a but approximately 6 times smaller than the entire DNAPL-impacted area at the Montrose Site. The Air Force estimates that between 600,000 and 1.4 million gallons of LNAPL (approximately 4 to 9 million pounds) are present in the subsurface at OU2, which is approximately 8 to 18 times more contaminant volume than is believed to be present at the Montrose Site.

Steam injection activities were initiated in October 2008 and are expected to run for approximately one year. It is noted that it has taken approximately 6 years for the Air Force to execute this pilot project. The Air Force has questioned the potential effectiveness of the TEE given the lower permeability soils present in portions of the saturated zone and speculates that a lower percentage of LNAPL mass would be removed by TEE.

Groundwater occurs at approximately 160 to 170 feet bgs (as of January 2008), and steam is injected into two zones: the Upper Water-Bearing Zone (WBZ) from 170 to 195 feet bgs and the Lower WBZ from 210 to 240 feet bgs. A 15-foot thick low permeability zone separates the two WBZs. Although the Lower WBZ is composed of alternately fine and coarse-grained layers, the degree of layering is not as significant as at the Montrose Site. The Upper WBZ is also composed of alternating fine and coarse-grained layers (slightly higher percentage of fine-grained soils than the Lower WBZ), but there is a high permeability cobble zone overlying the water table that will assist with recovering LNAPL vapors and steam.

Considering the thickness of the DNAPL-impacted interval (45 feet), the highly layered nature of the saturated UBA, and the unusual nature of the Montrose DNAPL, this RA likely would be the most complicated thermal remediation ever attempted. All of these factors increase the degree of uncertainty related to the effectiveness of the RA at the Site, as described for RA 5a. The treatment area considered by this RA is approximately 7 times larger than the focused treatment area considered by RA 5a. Large treatment areas are subject to a higher potential for non-uniform heating and preferential steam flow, resulting in "cold spots" where the effectiveness of the thermal technology will be reduced. Large treatment areas are also subject to a higher potential for downward migration to occur through discontinuous silt layers, since a much higher number of potential discontinuities would be encountered within the larger treatment area. Steam injection within the previously residual DNAPL areas has the potential to cause MCB in the subsurface to migrate if vapors are not effectively recovered. Unrecovered MCB vapors may condense in another portion of the saturated UBA. In addition, the effectiveness of the hot floor over such a large area is likely to be less effective, as the potential for cold spots increases.

Under RAs 5a and 5b, there is an increased potential for heated vapors or contaminated steam to be accidentally released to atmosphere as a fugitive emission. The higher temperatures and pressures associated with RAs 5a and 5b can result in aboveground piping failure or accelerated corrosion. For example, the plastic piping materials (CPVC) used at the Silresim Superfund Site suffered a complete loss of mechanical integrity during ERH pilot testing, releasing heated vapors and steam to atmosphere. Similarly, contaminated steam or vapors can escape to surface through previously drilled borings or wells that are not able to withstand the elevated temperatures associated with these RAs. For example, at the SCE Visalia site and despite significant participation by EPA and thermal remediation experts, one well suffered a catastrophic failure due to incompatibility of the bentonite annular seal materials with the elevated temperatures of the full-scale steam remedy. Steam flow to surface was so significant as to disperse sediment up to 200 feet from the well, a portion of which impacted off-site areas. Additionally, the subsurface will remain hot even if remediation system operations are interrupted. VOC vapors would continue to be generated in-situ even when the remediation system is not in operation. Long periods of system downtime, without adequate soil vapor recovery, have the potential to cause VOC migration in the unsaturated zone. Fugitive emissions, if any, during remedy implementation would reduce the protectiveness of RAs 5a and 5b in the short-term.

This RA would additionally include the effectiveness offered by the components of RA 3. The VOC/DNAPL mass in the unsaturated zone would be significantly reduced by SVE, and VOC migration in soil gas would be controlled. The DDT component would be left in place but would not pose a risk to human health or the environment (DDT is not volatile and relatively insoluble in groundwater). If successful, this RA would be effective in protecting human health and the environment by limiting exposure to DNAPL-impacted soils and groundwater. Migration of the dissolved contaminant plume in groundwater would be controlled through hydraulic containment. Assuming an 80% MCB mass removal efficiency, the duration required for hydraulic containment in the saturated zone under this maximum DNAPL mass removal RA would be reduced from approximately 4,900 to 3,600 years (or longer, if thermal remediation is unable to achieve the assumed mass reduction). While there is some variability in the assumptions used in estimating the containment timeframes, this estimate is significant because it shows that hydraulic containment will be required for a very long duration, even following a successful thermal remediation. Therefore, the cost-benefit of such a large-scale DNAPL source zone treatment technology must be considered. ***Rank: Potentially Effective (but highly uncertain).***

Implementability. This full-scale steam injection RA would be even more difficult to implement than RA 5a, due to the increased size of the project. A significant amount of above- and below-ground infrastructure would be required to generate and deliver steam throughout the DNAPL-impacted zone. A large number of wells, between 160 and 184 remedy wells (steam injection, multiphase extraction, and temperature monitoring), would be required and would generate a significant amount of waste. This RA additionally includes implementation of SVE in the unsaturated zone, ex-situ vapor treatment, and ex-situ groundwater treatment. The treated groundwater, approximately 200 gpm, would be transferred to the Groundwater Remedy Treatment System for re-injection into the BFS and Gage. The re-injection flow from the DNAPL remedy would need to be considered during design of the Groundwater Remedy Treatment System. Implementation of a hot floor in the underlying BFS would additionally be required to attempt to reduce the risks associated with downward migration of DNAPL and steam condensate. This RA would require highly skilled operators and a high level of maintenance, including boiler maintenance and management of boiler brine waste. Another factor affecting the implementability of this RA is the limited number of steam vendors, as indicated for RA 5a.

The carbon footprint of this RA is very high, approximately 175 million pounds of greenhouse gases, and by far the highest considered in this FS. High carbon footprints would not meet EPA green remediation initiatives or advance the goals of the California Global Warming Solutions Act of 2006, which are TBCs for this FS. Pursuant to AB 32, the California Air Resources Board has promulgated mandatory greenhouse gas reporting regulations that likely would be triggered by this RA (17 CCR §95100-95133). If this RA were to be implemented, Montrose may be required to submit annual reports, verified by a third party, containing detailed information on fuel consumption, greenhouse gas emissions, and electricity usage. These reporting obligations would make this RA more difficult to implement. Similarly, EPA recently has proposed mandatory federal greenhouse gas reporting regulations that likely would be triggered by this RA (Docket No. EPA-HG-OAR-2008-0508). If ultimately adopted, such federal regulations would make this RA even more difficult to implement. In general, both the State and Federal reporting regulations are triggered by facilities that emit more than 25,000 metric tons of carbon dioxide per year, not including indirect emissions attributable to electricity usage. The pertinent operations associated with this RA are expected to exceed the 25,000 metric ton threshold on an annual basis. Finally, the high GHG emissions generated by RA 5b are not consistent with the Obama administration's plans to reduce GHG emissions nationwide in an effort to mitigate the effects of global warming. ***Rank: Difficult to Implement.***

Cost. The relative cost of this large full-scale steam injection RA is very high. Implementation of steam injection over an area of 160,000 square feet and volume of 267,000 cubic yards would be one of the largest thermal remediation projects ever conducted in the United States. High well installation and waste management costs would be incurred under this RA. The energy requirement for this large thermal remediation project is exceptionally high, between 594,000 and 891,000 MCF of natural gas, including a field pilot test. Implementation of a hot floor in the underlying BFS substantially increases the cost of this RA and would increase the thermal treatment volume by approximately 22%. Additionally, the hot floor wells, up to 77 steam injection and multiphase extraction, are costly to install since conductor casings are required to isolate the DNAPL-impacted UBA during drilling. Combined with the infrastructure requirements associated with SVE in the unsaturated zone, ex-situ soil vapor treatment, and ex-situ groundwater treatment, the relative cost of this RA is very high. Because the estimated duration of hydraulic containment following this full-scale steam injection RA would not be meaningfully reduced, and would remain at approximately 3,600 years, the merits of implementing such a high cost RA must be considered.

While a small number of steam injection case sites have been implemented on a large-scale, all of them differ from the Montrose Site in significant respects and were either fully or partially funded by government agencies. The SCE Visalia Site was a technology demonstration project under partnership with Lawrence Livermore National Labs, a U.S. Department of Energy organization. Pacific Wood Treating had declared bankruptcy, and the thermal remedy at that site is being implemented by the Port of Ridgefield and State of Washington, with grants from both EPA and the U.S. Department of Housing and Urban Development. The Savannah River Site is being implemented by the U.S. Department of Energy (DOE). A full-scale steam injection RA at the Montrose Site, if implemented, may be the largest privately funded thermal remediation project and would be a significant financial burden for Montrose. The financial burden to Montrose would be far more significant, if not prohibitive, than the financial burden to the Federal Government or State agencies for the thermal remediation projects listed above.

For example, DOE's annual discretionary budget for environmental programs in 2008 was approximately 6.3 billion dollars, representing approximately 26% of the total annual DOE discretionary budget. Implementation of a high cost full-scale thermal remedy at a DOE site cannot be used as justification for implementing a high cost full-scale thermal remedy at the Montrose Site. While technical comparisons between the sites are discussed, one fundamental and indisputable difference is that Montrose does not possess the financial resources of the government agencies funding many of the large-scale thermal remediation projects. As a result, the cost criterion must be given serious consideration during remedy evaluation.

It is not unusual for the high cost of a full-scale thermal remedy to impact remedy evaluation and selection. For example, at the Silresim Superfund Site in Lowell, Massachusetts, full-scale thermal remedy costs between $20 and $40 million were identified following an ERH pilot test conducted in 2003 to treat soil volumes between 126,000 and 262,000 cubic yards. However, at that site, EPA determined that full-scale thermal remediation was not cost effective. EPA reported that approximately $28 million in funding had been established for site remediation from a group of potentially responsible parties. Instead, a focused thermal treatment alternative, targeting 65,000 cubic yards at an estimated cost of $13 million, has been selected for implementation at the Silresim Superfund Site (EPA, 2008f; Explanation of Significant Differences).

Further, climate change regulation is expected to increase the costs of both natural gas and electricity because upstream suppliers of these commodities are expected to be regulated at both the State and Federal level. In other words, as a price is placed on carbon emissions, whether directly via a carbon tax or, more likely, indirectly via State and/or Federal cap-and-trade regimes, the cost of carbon-intensive forms of energy (e.g., natural gas and non-renewably generated electricity) will increase. Such increased costs would add additional cost to this RA. ***Rank: Very High.***

Retain for Detailed Analysis? The scale and complexity of a full-scale steam injection RA at the Montrose Site would be unprecedented. While a handful of other large-scale thermal remediation sites have been implemented, none are similar to Montrose in terms of contaminant type and geology. Additionally, the size of the full-scale RA is significantly larger than the average size applied at other case sites. The focused treatment area as considered by RAs 5a and 6a are far more consistent with the application of thermal remediation technologies at other sites.

This full-scale steam injection RA may be the largest privately funded thermal remedy ever implemented. The financial burden to Montrose to fund a thermal remedy of this size would be prohibitive. Other large-scale thermal remedy projects were either funded by various government agencies or received grants from government agencies. Implementation of a high cost full-scale thermal remedy at a government site cannot be used as justification for implementing a high cost full-scale thermal remedy at the Montrose Site. Furthermore, the high cost of this RA is unjustified since long-term it would not meaningfully reduce the amount of time that hydraulic containment would be required; particularly, containment would still be required for approximately 3,600 years. The potential benefit of implementing a full-scale remedy in order to significantly shorten the remedy duration and eliminate the need for long-term containment would not be recognized at the Montrose Site. Like many DNAPL sites, there are significant technical challenges to removing sufficient mass as to justify the high cost of the RA. While there is some variability in the assumptions used to estimate containment timeframes, the estimates clearly demonstrate that even a full-scale thermal remedy would not meet MCLs, and thus, would not eliminate the need for long-term hydraulic containment nor significantly reduce the duration of necessary containment. Residual DNAPL (immobile in the environment) is estimated to occur over 84% of the DNAPL-impacted area but represent only 40% of the estimated DNAPL mass. Based on the above factors, there does not appear to be any technical merit or cost benefit in thermally remediating areas containing residual DNAPL.

There is only one steam injection vendor with the potential capability to implement a remedy of this scale, which significantly limits the implementability of this RA. It is also unclear if the technology vendor would be able to obtain a performance bond or other form of financial assurance and performance guarantee for a project of this scale.

The carbon footprint for this full-scale RA is exceptionally large (approximately 175 million pounds of greenhouse gases), requiring approximately 1.1 million trees to offset the carbon dioxide generated by the RA. This exceptionally large carbon footprint is not consistent with EPA green remediation initiatives and would not advance the goals of the California Global Warming Solutions Act of 2006, which are TBCs for this FS, and is more than four times higher than the carbon footprint of the steam injection focused area considered in RA 5a.

Like RA 5a, steam injection is dependent on permeable soils and is not as applicable to the low permeability saturated UBA. There is an increased risk of contaminant spreading by steam injection, and implementation of this full-scale steam injection RA adjacent to the commercial building located at the former Boeing Realty Corporation property may increase the risk of human exposure. Steam is less frequently implemented than ERH and has an increased risk of downward mobilization. For this RA, a hot floor would be required to reduce the potential for downward mobilization. The size of the hot floor required for this RA would be the largest ever implemented, and despite the size, the potential effectiveness would be highly uncertain. Steam injection hot floors are very infrequently implemented (none at a comparable site), and the potential for non-uniform heating and failure of the hot floor at the large scale increases proportionally. For all the reasons identified above, this full-scale steam injection RA is not retained for detailed evaluation. ***Retain? No.***

5.2.7 REMEDIAL ALTERNATIVE 6A – ERH OVER FOCUSED TREATMENT AREA

This RA includes four GRAs: (1) ERH over a focused treatment area, (2) SVE in the unsaturated zone, (3) institutional controls, and (4) containment in the saturated zone as required by the Groundwater ROD.

Effectiveness. The DNAPL mass and mobility in the saturated UBA may be reduced under this RA within a focused treatment area, consistent with the estimated extent of mobile DNAPL at the Property. ERH has the potential to reduce DNAPL mass, both residual and mobile, within the focused treatment area through MCB volatilization. The effectiveness of this RA would be similar to RA 5a, with the exception that heating of the saturated UBA within the focused treatment area is accomplished via ERH instead of steam injection. However, ERH has not been pilot tested at the Site, and its potential effectiveness is highly uncertain. ERH is fundamentally different from steam injection because heating is not as significantly affected by soil permeabilities, and ERH is more commonly applied at sites with lower permeability soils such as the saturated UBA. Soils are heated through electrical resistivity, and therefore, soils with high resistivity will not be heated as effectively. The electrical resistivity of the saturated UBA soils at the Montrose Site has not been measured and is uncertain. Variances in electrical resistivities can result in non-uniform heating, leading to desaturation between electrodes and loss of electrical current in those soils. Non-uniform heating and desaturation of soils is a common performance problem observed at other ERH sites. At those sites, the electrical resistance of the desaturated soils climbs thereby decreasing electrical current flow and reducing the effectiveness of an ERH RA.

The ERH electrodes would be spaced 21 feet apart, which is a relatively low electrode density for ERH. At some thermal remediation sites, electrodes are spaced less than 10 feet apart. Increased spacing of electrodes increases the potential for reduced heating and development of cold spots. Additionally, water influx from the surrounding or underlying formation can cool the target treatment area increasing the duration required for heating. The groundwater flow through the UBA is primarily horizontal, and therefore, groundwater influx may result in some cooling along the upgradient boundary of the thermal treatment area (although the horizontal gradient is not significant). The vertical gradient at the Site is slightly downward (from the UBA to the BFS), and therefore, significant cooling from the underlying

BFS would not be expected. However, the depth to water in the BFS is only slightly deeper than the UBA, so some cooling from the underlying BFS may occur at the bottom of the thermal treatment zone. Water influx has been identified as one of the primary reasons for lower contaminant mass removal efficiencies at other ERH sites.

The 45-foot thickness of the DNAPL-impacted UBA at the Montrose Site may pose significant challenges for effective and uniform heating by ERH. A treatment interval of 30-feet or less is typically implemented at ERH sites. Achieving target temperatures at depth within the saturated zone has proven to be problematic at several ERH case sites, including the Paducah Gaseous Diffusion Plant in Kentucky. Soil temperatures of only 30°C to 70°C were achieved between 95 and 105 feet bgs at the Paducah Site because the thick treatment interval resulted in poor performance of the deep electrodes. The excessive weight of the steel shot backfill resulted in structural failure of the insulating materials used to separate each of six electrical elements. The electrodes functioned as a single element with no vertical differentiation, and as a result, were not effective in heating the deeper soils. If ERH was unable to heat the deeper soils at the Montrose Site (also to 105 feet bgs) to target temperatures, then RA 6a would not be as effective in reducing MCB mass. Thermal remediation has not been implemented at depth and over a thick saturated interval at sites that are comparable to Montrose. Although the Pemaco Superfund Site, has been identified as a site where thermal remediation has been implemented at depth (CH2M Hill, 2007), this site is not comparable to the Montrose Site for reasons identified below and in Appendix L.

> <u>Pemaco Superfund Site:</u> ERH was implemented over an area of 14,000 square feet and from 35 to 95 feet bgs. The saturated thickness at this site was 35 feet, from 60 to 95 feet bgs. However, no DNAPL was present at this site. The thermal remediation primarily addressed dissolved-phase TCE, and less than 100 pounds of TCE was removed during the thermal remedy. Furthermore, the target temperature was not reached throughout the treatment zone due to non-uniform heating, primarily from asymmetrical electrode spacing, low efficiency of long electrodes, and slanted electrodes located on the east side of the treatment area.

Although heating heterogeneous soils such as the saturated UBA is less problematic for ERH, it may be problematic for recovering volatilized contaminants by SVE. The extraction system efficiency is critical for a successful ERH remedy, and VOCs that are not effectively recovered will cool and re-condense in the subsurface, reducing the effectiveness of the ERH remedy. VOCs that are not effectively recovered, or not able to migrate upward to the unsaturated zone for recovery, may also migrate laterally and outside the thermal treatment zone, which would not be consistent with DNAPL RAOs. However, ERH is implemented on a higher well density increasing the likelihood of recovering volatilized VOCs to some degree. Although ERH is less prone to downward mobilization because it relies exclusively on volatilization and does not flush DNAPL laterally, the higher well density increases the potential for pooled DNAPL to mobilize downward along an ERH electrode or well casing prior to heating as indicated in Section 2.6.6 (Queen's University, 2009).

ERH has never been applied to a DNAPL site where either MCB or DDT was a primary component of the DNAPL. The co-boiling point for the Montrose DNAPL is 96°C, which approaches the upper limit of potential effectiveness for ERH (i.e., 100°C). ERH has been most frequently implemented at sites impacted with TCE and petroleum hydrocarbons, which have much lower co-boiling points than MCB (TCE co-boiling point is 73°C and boiling point is 87°C). The effectiveness of ERH to thermally treat soils impacted with an MCB DNAPL has never been demonstrated at either pilot or full-scale.

It is Montrose's understanding that currently, EPA is considering ERH as a remedial action for LNAPL at the Del Amo Superfund Site. It is also understood that Shell, an RP for that site, has raised concerns about the potential application of this technology to EPA Region 9 staff, and to EPA's National Remedy Review Board. Shell has pointed out that ERH is an inappropriate remedy based on several factors including the heavily developed nature of the Del Amo Site, the potential for associated health and safety risks to onsite workers and the public, and the inevitable disruptions to local businesses operating in close proximity to the proposed treatment areas. Montrose strongly agrees with Shell's concerns regarding these issues, but further maintains that should ERH ultimately be selected by EPA for application at the Del Amo Site, that should not serve as a precedent for selecting this remedy for the Montrose Site. Although the geology in one of the LNAPL source areas, located in the western portion of the Del Amo Site, is similar to the Montrose Site, there are significant factual differences between the two sites.

> The LNAPL at the Del Amo Site is primarily composed of benzene, which has a co-boiling point of 69°C and a boiling point of 80°C at 1 atmosphere, both of which are well below the boiling point of water (100°C at 1 atmosphere). In contrast, the Montrose DNAPL has a co-boiling point of 96°C and a boiling point of 132°C at 1 atmosphere. Approximately 55% more electrical energy would be required to raise soil temperatures to 96°C as compared to 69°C. Also, the co-boiling point of the Montrose DNAPL (96°C) approaches the boiling point of water (100°C at 1 atmosphere), increasing the potential for desaturation of soils during ERH. Desaturation increases the soil resistivity and reduces electrical current flow in the treatment zone, thereby reducing the effectiveness of ERH. Furthermore, the DDT-component of the Montrose DNAPL will not be volatilized by ERH and would remain in-situ.

Additionally, benzene is approximately six times more volatile than the MCB-component of the Montrose DNAPL. Benzene has a vapor pressure of approximately 81 millimeters of mercury at 20°C, whereas MCB has a vapor pressure of only 12 millimeters of mercury at 20°C. MCB is not as readily converted to vapor-phase as benzene. Benzene is also less dense than water and floats at the groundwater surface as an LNAPL. Therefore, implementation of ERH at the Del Amo Site does not present a significant risk of downward mobilization of benzene. In contrast, the Montrose DNAPL is more dense than water and poses a significant risk of downward migration.

Due to a rising water table, the LNAPL at the Del Amo Site has been smeared across the saturated zone between approximately 60 feet bgs and a maximum depth of 85-90 feet bgs (depending on LNAPL source area). In contrast, DNAPL impacts to soil were observed at depths greater than 85-90 feet bgs in more than 15 investigation borings at the Montrose Site. The treatment interval at the Montrose Site would be from 60 to 105 feet bgs, at least 15 feet thicker and deeper than at the Del Amo Site. Effective heating of thick saturated intervals (greater than 30 feet thick) has proven to be problematic at other ERH sites (e.g., Paducah Gaseous Diffusion Plant Site).

Additionally, the largest LNAPL source area at the Del Amo Site (Source Area 3; 50,000 square feet) is approximately 3 times smaller than the DNAPL-impacted area at the Montrose Site (160,000 square feet). Treatment of the entire DNAPL-impacted area at the Montrose Site would be the largest ERH project ever implemented and would not be consistent with the application of ERH at other sites, which treated much smaller target areas.

Differences between the Del Amo and Montrose Sites include NAPL properties, NAPL distribution, lithology (in three of the LNAPL source areas), treatment area depth and thickness, and the size of the treatment area, among others. In light of the significant differences between the two sites and associated NAPLs, selection of an ERH remedy for the Del Amo Site does not support the candidacy of ERH for the Montrose Site.

This RA would additionally include the effectiveness offered by the components of RA 3. The VOC/DNAPL mass in the unsaturated zone would be significantly reduced by SVE, and VOC migration in soil gas would be controlled. If successful, this RA would be effective in protecting human health and the environment by limiting exposure to DNAPL-impacted soils and groundwater. Migration of the dissolved contaminant plume in groundwater would be controlled through hydraulic containment. Assuming an 80% MCB mass removal efficiency, the duration required for hydraulic containment in the saturated zone under this RA would be reduced from approximately 4,900 to 4,400 years (or longer, if thermal remediation is unable to achieve the assumed mass reduction). While there is some variability in the assumptions used in estimating the containment timeframes, this estimate is significant because it shows that even a successful thermal remediation will not meaningfully reduce the required duration of hydraulic containment. ***Rank: Potentially Effective (but uncertain)***

Implementability. This RA would be difficult to implement. The implementability of this RA is the same as for RA 5a, with heating of the saturated UBA by ERH instead of steam injection. A relatively large number of electrodes (87) would be required to treat the focused treatment area, creating a significant amount of waste requiring management and disposal, and increasing the risk of downward DNAPL pool mobilization prior to the start of heating. This RA would additionally require implementation of SVE in the unsaturated zone, ex-situ vapor treatment, and ex-situ groundwater treatment. This RA would require skilled operators and a high level of maintenance. However, unlike steam injection, three qualified ERH vendors (TRS, CES, and MC2) are available to implement this RA, and ERH is more frequently implemented today than steam injection. ERH is an energy-intensive remedial technology, and the amount of energy required to heat the focused treatment area (7,640 megawatt-hours) is significant. The resulting carbon footprint (14 million pounds of greenhouse gases) is also significant and not in accordance with EPA green remediation initiatives or the California Global Warming Solutions Act of 2006, which are TBCs for this FS. ***Rank: Difficult to Implement.***

Cost. The relative cost of this focused treatment ERH RA is high. The cost of this RA is comparable to RA 5a, which addresses the same focused treatment area using steam injection. The infrastructure requirements for this RA are very similar to that of RA 5a, except that the number of ERH electrodes required (87) exceeds the number of steam injection wells. The energy requirement for this RA is high at 7,640 megawatt-hours, even though it addresses a focused treatment area. However, because ERH is less prone to downward mobilization risks, a hot floor may not be necessary in the underlying BFS which would reduce the cost of this RA below that of the equivalent steam injection RA.

Further, climate change regulation is expected to increase the costs of both natural gas and electricity because upstream suppliers of these commodities are expected to be regulated at both the State and Federal level. In other words, as a price is placed on carbon emissions, whether directly via a carbon tax or, more likely, indirectly via State and/or Federal cap-and-trade regimes, the cost of carbon-intensive forms of energy (e.g., natural gas and non-renewably generated electricity) will increase. Such increased costs would add additional cost to this RA. ***Rank: High.***

Retain for Detailed Analysis? The ERH component of this RA has not been bench or field pilot tested, and therefore, the potential effectiveness of ERH at the Site is uncertain. However, although high in cost, if effective, ERH would reduce DNAPL mass and mobility in the saturated UBA within a focused treatment area, which is comparable in size to those implemented at other ERH sites. ERH is potentially applicable to the geology of the saturated UBA and is not significantly dependent on soil permeability for heating the subsurface. Further, ERH does not hydraulically displace DNAPL and is not significantly prone to lateral spreading of contaminants outside the treatment area (i.e., lower risk to adjacent industrial building at the former Boeing Realty Corporation property), unless MCB vapors are not effectively recovered by SVE and the multiphase extraction wells. ERH uses a relatively high density of wells and would offer improved lateral and vertical control over heating and contaminant recovery. ERH is not signficantly prone to downward mobilization, and as a result, implementation of a hot floor in the underlying BFS may not be required. Three technology vendors are available to implement ERH, and ERH is the most frequently implemented thermal technology. The carbon footprint of this focused treatment ERH RA is significantly lower than the carbon footprint of full-scale ERH RA 6b and would generate approximately 76% fewer greenhouse gases, although the carbon footprint for this RA is still substantial and incompatible with State and Federal greenhouse gas emission reduction objectives.

The SVE component of this RA would reduce the mass of VOCs and DNAPL in the unsaturated zone, thereby increasing the protectiveness of the RA to groundwater and controlling VOC migration in soil gas. The institutional controls component of the RA would protect human health by controlling the contaminant exposure pathways. The hydraulic containment component of this RA will prevent migration of dissolved-phase contaminants in the saturated zone and will reduce DNAPL mass in the long-term by dissolution. This RA is retained for detailed evaluation. ***Retain? Yes.***

5.2.8 Remedial Alternative 6b – ERH over Entire DNAPL-Impacted Area

This RA includes four GRAs: (1) ERH over the entire DNAPL-impacted area, (2) SVE in the unsaturated zone, (3) institutional controls, and (4) containment in the saturated zone as required by the Groundwater ROD.

Effectiveness. This RA reflects the highest level of remedial action considered in the FS and its effectiveness would be similar to RA 5b, except that heating of the entire DNAPL-impacted area would be accomplished by ERH instead of steam injection and it would present a decreased risk of downward mobilization because contaminants would not be concentrated at a steam front. The entire DNAPL-impacted area, including both mobile and residual DNAPL, would be thermally treated under this RA which includes the source areas at the CPA and east of the CPA where the DNAPL generally thins and occurs in lower saturations. This RA (and RA 5b) has the potential to remove the most DNAPL mass, although it would not reduce the DNAPL mobility over RAs 4, 5a, and 6a, nor would it meaningfully reduce the amount of time required for groundwater containment. Electricity would be delivered to more than 450 electrodes to heat the saturated UBA, volatilizing the MCB component of the DNAPL for removal in soil vapor. This RA has the same effectiveness as RA 6a, except that it would additionally remove DNAPL mass from outside the focused treatment area where 40% of the DNAPL mass is estimated to occur at residual saturations (and therefore immobile in the environment).

However, as previously indicated in Section 4.6.1 and if implemented, this RA would be the largest ERH project ever conducted in the United States. The target treatment area and volume for this RA would be 160,000 square feet and 267,000 cubic yards. By comparison, the largest ERH treatment area and volume previously implemented was reported as 91,000 square feet and 80,000 cubic yards. There are no sites comparable to the Montrose Site where ERH has been implemented. Given the thick treatment interval, highly layered UBA, and unusual nature of the Montrose DNAPL, this RA would likely be the most complicated ERH remedy ever implemented. The treatment area considered by this RA is approximately 7 times larger than the focused treatment area considered by RA 6. Large treatment areas are subject to a higher potential for non-uniform heating, resulting in "cold spots" where the effectiveness of the thermal technology will be reduced. ERH within the previously residual DNAPL areas has the potential to cause migration of MCB in the subsurface if vapors are not effectively recovered. Unrecovered MCB vapors may condense in another portion of the saturated UBA. The number of ERH electrodes required would be very high (456) despite a relatively high electrode spacing of 21 feet. The very large number of wells required by this RA (a total of 729 electrodes, multiphase extraction wells, and temperature monitoring points) significantly increases the potential for downward DNAPL migration to occur as a result of drilling activities. All of these factors increase the uncertainty of the effectiveness of RA 6b at the Site.

RAs 6a and 6b present an increased potential for heated vapors or contaminated steam to be accidentally released to atmosphere as a fugitive emission. The higher temperatures and pressures associated with RAs 6a and 6b can result in aboveground piping failure or accelerated corrosion. For example, the plastic piping materials (CPVC) used at the Silresim Superfund Site suffered a complete loss of mechanical integrity during ERH pilot testing, releasing heated vapors and steam to the atmosphere. Similarly, contaminated steam or vapors can escape to surface through previously drilled borings or wells that are unable to withstand the elevated temperatures associated with these RAs. For example, at the SCE Visalia site, one well suffered a catastrophic failure due to incompatibility of the bentonite annular seal materials with the elevated temperatures of the full-scale steam remedy as discussed previously.

Additionally, the subsurface will remain hot even if remediation system operations are interrupted. VOC vapors would continue to be generated in-situ even after the remediation system is shut down. Long periods of system downtime without adequate soil vapor recovery have the potential to cause VOC migration in the unsaturated zone. Fugitive emissions, if any, during remedy implementation would reduce the protectiveness of RAs 6a and 6b in the short-term.

Additionally, this RA would include the effectiveness offered by the components of RA 3. The VOC/DNAPL mass in the unsaturated zone would be significantly reduced by SVE, and VOC migration in soil gas would be controlled. If successful, this RA would be effective in protecting human health and the environment by limiting exposure to DNAPL-impacted soils and groundwater. Migration of the dissolved contaminant plume in groundwater would be controlled through hydraulic containment. Even if highly effective, this RA will not significantly reduce the required duration of hydraulic containment. Assuming an 80% MCB mass reduction over the entire DNAPL-impacted area, the duration required for hydraulic containment in the saturated zone would only be reduced from approximately 4,900 to 3,600 years (or longer, if ERH is unable to achieve the assumed mass reductions). Therefore, the cost-benefit of such a large-scale DNAPL source zone treatment technology must be considered. ***Rank: Potentially Effective (but uncertain).***

Implementability. The implementability of this RA is very similar to that of RA 5b, with heating by ERH instead of steam injection. This RA would be difficult to implement. An exceptionally large number of electrodes would be required (456) to treat the DNAPL-impacted area and would create a significant amount of waste requiring management and disposal. This RA would additionally require implementation of SVE in the unsaturated zone, ex-situ vapor treatment, and ex-situ groundwater treatment.

This RA would require highly skilled operators and a high level of maintenance. Unlike steam injection, three qualified ERH vendors (TRS, CES, and MC2) are available to implement this RA, and ERH is more frequently implemented today than steam injection, although not at the size of this full-scale RA. ERH is an energy-intensive remedial technology, and the amount of energy required to heat the entire DNAPL-impacted area (53,400 megawatt-hours) is significant. The resulting carbon footprint (58 million pounds of greenhouse gases) is also significant and not in accordance with EPA green remediation initiatives or the California Global Warming Solutions Act of 2006, which are TBCs for this FS. Pursuant to AB 32, the California Air Resources Board has promulgated mandatory greenhouse gas reporting regulations that likely would be triggered by this RA (17 CCR §95100-95133). If this RA were to be implemented, Montrose may be required to submit annual reports, verified by a third party, containing detailed information on fuel consumption, greenhouse gas emissions, and electricity usage. These reporting obligations would make this RA more difficult to implement. Similarly, EPA recently has proposed mandatory federal greenhouse gas reporting regulations that likely would be triggered by this RA (Docket No. EPA-HG-OAR-2008-0508). If ultimately adopted, such federal regulations would make this RA even more difficult to implement. In general, both the State and Federal reporting regulations are triggered by facilities that emit more than 25,000 metric tons of carbon dioxide per year, not including indirect emissions attributable to electricity usage. The pertinent operations associated with this RA are expected to exceed the 25,000 metric ton threshold on an annual basis. Finally, the high GHG emissions generated by RA 6b are not consistent with the Obama administration's plans to reduce GHG emissions nationwide in an effort to mitigate the effects of global warming. ***Rank: Difficult to Implement.***

Cost. The relative cost of this large ERH RA is very high. Implementation of ERH over an area of 160,000 square feet and volume of 267,000 cubic yards would be the largest ERH project ever conducted in the United States. High well installation and waste management costs would be incurred under this RA. The infrastructure requirements for this RA are very similar to that of RA 5b (associated with SVE in the unsaturated zone, ex-situ soil vapor treatment, and ex-situ groundwater treatment), except that the number of ERH electrodes required is higher than the number of steam injection wells under RA 5b. However, because ERH is less prone to downward mobilization risks, a hot floor may not be necessary in the underlying BFS which would reduce the cost of this RA below that of the equivalent steam injection RA. The energy requirement for this RA would be exceptionally high at 53,400 megawatt-hours, including a field pilot test. Because the estimated duration of hydraulic containment following this RA would not be meaningfully reduced and would remain at approximately 3,600 years, the merits of implementing such a high cost RA must be considered.

If implemented, this RA would be the largest and probably the most expensive ERH RA ever implemented in the United States and highly financially burdensome for Montrose. The financial burden to Montrose would be far more significant, if not prohibitive, than the financial burden to the Federal Government or State agencies at some other full-scale thermal remediation sites. For example, a full-scale ERH remedy is currently being implemented at the Paducah Gaseous Diffusion Plant to treat an estimated 80,000 cubic yards of DNAPL-impacted soil at an estimated cost of approximately $19.7 MM. However, the Paducah Plant is a DOE Site, and implementation of a high cost full-scale thermal remedy at a DOE site cannot be used as justification for implementing a high cost full-scale thermal remedy at the Montrose Site. DOE's annual discretionary budget for environmental programs in 2008 was approximately 6.3 billion dollars. One fundamental and indisputable difference in funding is that Montrose does not possess financial resources comparable to those of the government agencies funding many of the large-scale thermal remediation projects. As a result, the cost criterion must be given serious consideration during remedy evaluation. It is not unusual for the high cost of a full-scale thermal remedy to impact remedy evaluation and selection. As previously indicated, EPA determined that full-scale ERH remediation of 126,000 to 262,000 cubic yards at the Silresim Superfund Site, at an estimated cost of $20 to $40 MM, was not cost effective. Instead, EPA has selected implementation of a focused thermal treatment alternative for the Silresim Superfund Site, targeting 65,000 cubic yards at an estimated cost of $13 MM (EPA, 2008f; Explanation of Significant Differences).

Further, climate change regulation is expected to increase the costs of both natural gas and electricity because upstream suppliers of these commodities are expected to be regulated at both the State and Federal level. In other words, as a price is placed on carbon emissions, whether directly via a carbon tax or, more likely, indirectly via State and/or Federal cap-and-trade regimes, the cost of carbon-intensive forms of energy (e.g., natural gas and non-renewably generated electricity) will increase. Such increased costs would add additional cost to this RA. ***Rank: Very High.***

Retain for Detailed Analysis? The scale and complexity of a full-scale ERH RA at the Montrose Site would be unprecedented. No other ERH site has ever been implemented to this size, scale, and complexity. Additionally, the size of the full-scale RA is significantly larger than the average sized ERH technology applied at other case sites (approximately 6 to 8 times larger). The focused treatment area as considered by RAs 5a and 6a are far more consistent with the application of thermal remediation technologies at other sites.

This full-scale ERH RA, if implemented, would be the largest privately funded thermal remedy ever implemented. The financial burden to Montrose to fund a thermal remedy of this size would be prohibitive. Other large-scale thermal remedy projects were either funded by, or received grants from, various government agencies. Implementation of a high cost full-scale thermal remedy at a government site cannot be used as justification for implementing a high cost full-scale thermal remedy at the Montrose Site. Furthermore, the high cost of this RA is unjustified since the amount of time required for long-term hydraulic containment would not be meaningfully reduced and containment would remain necessary for many centuries. Like many DNAPL sites, there are significant technical challenges to removing sufficient mass as to justify the high cost of the RA. While there is some variability in the assumptions used to estimate containment timeframes, the estimates clearly demonstrate that even a full-scale thermal remedy will not eliminate the need for long-term hydraulic containment. Based on the above factors, there does not appear to be any technical merit or cost benefit in thermally remediating areas containing residual DNAPL.

The carbon footprint for this full-scale RA is exceptionally large (approximately 58 million pounds of greenhouse gases), requiring approximately 373,000 trees to offset the carbon dioxide generated by the RA. This exceptionally large carbon footprint is not consistent with EPA green remediation initiatives or the California Global Warming Solutions Act of 2006, which are TBCs for this FS, and is more than five times higher than the carbon footprint of the ERH focused treatment area considered in RA 6a and nearly thirty times higher than the carbon footprint of the hydraulic displacement RA (RA 4).

The number of electrodes, multiphase extraction wells, and temperature monitoring points required by a full-scale ERH RA would be excessive (729 total locations) and significantly increase the risk of vertical DNAPL mobilization during or as a result of drilling. Additionally, the amount of waste generated by the large number of wells would be significant. It is also unknown if any of the three ERH vendors would have sufficient financial assurance to obtain a performance bond or other type of financial assurance or performance guarantee. For all the reasons identified above, this full-scale ERH RA is not retained for detailed evaluation. ***Retain? No.***

5.3 SUMMARY OF ALTERNATIVES RETAINED FOR DETAILED EVALUATION

Six of the nine RAs screened in Section 5.2 were retained for detailed evaluation. Three of the RAs retained for evaluation are more effective in accelerating DNAPL mass and mobility reduction in the saturated UBA. The No Action RA is retained in compliance with NCP guidelines. Although the remaining two RAs do not accelerate DNAPL mass reduction in the saturated zone, DNAPL mass is reduced over time by dissolution. Further, they are effective in protecting human health and the environment, and they would be successful in achieving the RAOs in the long-term. A summary of the intermediate screening evaluation is provided in **Table 5.2**, and the RAs retained for detailed evaluation are listed below:

RAs Retained for Detailed Evaluation

Remedial Alternative	**GRA Remedial Technologies/Process Options**
Remedial Alternative 1	No Action Containment (required by Groundwater ROD)
Remedial Alternative 2	Containment (required by Groundwater ROD) Institutional Controls
Remedial Alternative 3	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone)
Remedial Alternative 4	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) Hydraulic Displacement, with untreated water injection
Remedial Alternative 5a	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) Steam Injection, focused treatment area, with hot floor
Remedial Alternative 6a	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) ERH, focused treatment area, without hot floor

A detailed analysis of these remaining alternatives is provided in Section 6.

TABLES

Table 5.1
Carbon Footprint Analysis
DNAPL Remedial Alternatives
Montrose Superfund Site

Remedial Alternative		Electricity Generation + Natural Gas Use		Total Carbon Offsets & Equivalents	
		Mass of CO_2 Released[1]		Trees Required to Offset CO_2[2]	Acres Required to Support Trees[3]
		(lbs)	(Kg)		
RA 1	No Action	0	0	0	0
RA 2	ICs, Containment	NA[4]	NA	NA	NA
RA 3	SVE, ICs, Containment	2,193,343	994,884	14,199	24
RA 4	HD, SVE, ICs, Containment	4,212,050	1,910,554	27,267	45
RA 5a	Steam Injection over Focused Treatment Area, SVE, ICs, Containment	45,938,291	20,837,258	297,380	496
RA 5b	Steam Injection over Entire DNAPL-Impacted Area, SVE, ICs, Containment	175,488,417	79,600,207	1,136,019	1,893
RA 6a	ERH over Focused Treatment Area, SVE, ICs, Containment	13,677,997	6,204,235	88,544	148
RA 6b	ERH over Entire DNAPL-Impacted Area, SVE, ICs, Containment	57,617,074	26,134,665	372,982	622

Notes:
RA = Remedial Alternative
ICs = Institutional Controls
SVE = Soil Vapor Extraction
HD = Hydraulic Displacement
ERH = Electrical Resistance Heating
DNAPL = Dense Non Aqueous Phase Liquid
lbs = pounds
Kg = kilograms
CO_2 = carbon dioxide

1 US DOE Carbon Dioxide Emission Factors for Coal; US EPA.Compilation of Air Pollutant Emission Factors; California Energy Commission, LADWP Electricity Generation by Energy Source
2 Average carbon sequestration capability of trees = 70.1 Kg CO_2 per tree; Source = NewFields, Remediation Carbon Footprint Analysis, Central Chemical Superfund Site, May 2008
3 600 trees per acre; Source = NewFields, Remediation Carbon Footprint Analysis, Central Chemical Superfund Site, May 2008
4 Not Applicable. The Containment technology is part of the groundwater remediation and universal to all DNAPL Remedial Alternatives

Table 5.2
Intermediate Screening of DNAPL Remedial Alternatives
Montrose Superfund Site

Remedial Alternative	Remedial Technology Components	Technical Effectiveness	Implementability	Relative Cost	Retain for Detailed Evaluation? (Yes/No)
RA 1	• No Action • Hydraulic Containment	• Moderately effective • Hydraulic containment will prevent migration of dissolved-phase contaminants and reduce DNAPL mass in the long-term by dissolution; duration estimated at 4,900 years	• Implementable • Hydraulic containment required as component of groundwater remedy	• None	Yes
RA 2	• Institutional Controls • Hydraulic Containment	• Moderately effective • ICs will protect human health by controlling contaminant exposure pathways; land use/activities and Site access would be restricted • Hydraulic containment will prevent migration of dissolved-phase contaminants and reduce DNAPL mass in the long-term by dissolution; duration estimated at 4,900 years	• Implementable • ICs will be required as component of soil and groundwater remedies • Nearly all DNAPL occurs at Montrose Property where land use/activities can be restricted; deed restriction at adjacent former Boeing Realty Corporation property, if necessary, would require consent of land owner • Hydraulic containment required as component of groundwater remedy	• Low	Yes
RA 3	• SVE, Unsaturated Zone • Institutional Controls • Hydraulic Containment	• Highly effective (in permeable unsaturated soils) • SVE will reduce mass of VOCs/DNAPL in the unsaturated zone, increase protectiveness of groundwater, and control VOC migration in soil gas • SVE was field pilot tested at Site and removed VOCs at an elevated rate from PVS and unsaturated UBA • Excludes low permeability PD soils where SVE was found to be less effective • ICs will protect human health by controlling contaminant exposure pathways • Hydraulic containment will prevent migration of dissolved-phase contaminants and reduce DNAPL mass in the long-term by dissolution; duration estimated at 4,900 years	• Implementable • SVE is widely implemented; does not require highly skilled operators and large number of contractors are available to implement • Ex-situ vapor treatment required in compliance with air emission ARARs • ICs will be required as component of soil and groundwater remedies • Hydraulic containment required as component of groundwater remedy • Smallest carbon footprint (2.2 million pounds of greenhouse gases) meets global warming TBCs	• Low to Medium	Yes

TABLE 5.2 (continued)
Intermediate Screening of DNAPL Remedial Alternatives

Remedial Alternative	Remedial Technology Components	Technical Effectiveness	Implementability	Relative Cost	Retain for Detailed Evaluation? (Yes/No)
RA 4	• Hydraulic Displacement, untreated groundwater • SVE, Unsaturated Zone • Institutional Controls • Hydraulic Containment	• Effective for mobile DNAPL • HD will reduce DNAPL mass and significantly reduce DNAPL mobility; residual DNAPL is immobile in the environment (other than as source for dissolved-phase contaminants) • Highest saturations are most mobile; HD depletes saturations making DNAPL less and less mobile • Re-injection of untreated groundwater effective for hydraulic displacement of mobile DNAPL • HD modeling indicates that well spacings under 120 feet will effectively mobilize DNAPL to recovery wells; no downward migration below basal silty sand layer predicted by model • Well spacings of 25 and 50 feet are proposed and would be effective in mitigating potential for downward migration • HD was field pilot tested at Site and removed DNAPL at a moderate rate • SVE will reduce mass of VOCs/DNAPL in the unsaturated zone, increase protectiveness of groundwater, and control VOC migration in soil gas • ICs will protect human health by controlling contaminant exposure pathways • Hydraulic containment will prevent migration of dissolved-phase contaminants and reduce DNAPL mass in the long-term by dissolution; duration estimated at 4,700 years	• Implementable • Standard drilling methods can be used to install wells • No specialized equipment or highly skilled operators required • DNAPL is readily separated from groundwater • Routine maintenance can abate precipitate fouling effects • ROD re-injection limits would need to be waived, as they were for pilot testing • SVE with ex-situ vapor treatment required; must meet air emission ARARs • ICs will be required as component of soil and groundwater remedies • Hydraulic containment required as component of groundwater remedy • Relatively small carbon footprint (4.2 million pounds of greenhouse gases) meets global warming TBCs	• Medium	Yes

TABLE 5.2 (continued)
Intermediate Screening of DNAPL Remedial Alternatives

Remedial Alternative	Remedial Technology Components	Technical Effectiveness	Implementability	Relative Cost	Retain for Detailed Evaluation? (Yes/No)
RA 5a	• Steam Injection with Hot Floor, Focused Treatment Area • SVE, Unsaturated Zone • Institutional Controls • Hydraulic Containment	• Potentially effective (but highly uncertain) • Steam injection may reduce DNAPL mass within a focused treatment area containing mobile DNAPL; 60% of the mass is located within 16% of the DNAPL-impacted area • Steam injection has not been field pilot tested at Site • Steam injection is dependent on soil permeability; steam will preferentially flow through high permeability soil layers; not well-suited to low permeability and heterogeneous UBA; was not assembled into formal RA at nearby Del Amo Site for this reason • Has never been applied to DNAPL composed of primarily MCB or DDT; MCB boiling point is higher than most other VOCs • Will mobilize and concentrate DNAPL at steam front; increased potential for lateral spreading and downward migration • Risk of spreading contaminants under industrial building at former Boeing Realty Corporation property • Steam injection well spacing is larger than HD well spacing; increased risk of not recovering DNAPL mobilized by steam injection • Steam condensate will become contaminated and may migrate downward if not effectively recovered • Hot floor in underlying BFS would be required but effectiveness has not been demonstrated at a comparable site • SVE will reduce mass of VOCs/DNAPL in the unsaturated zone, increase protectiveness of groundwater, and control VOC migration in soil gas • ICs will protect human health by controlling contaminant exposure pathways • Hydraulic containment will prevent migration of dissolved-phase contaminants and reduce DNAPL mass in the long-term by dissolution; required duration (4,400 years) not significantly reduced by high cost source area RA	• Difficult to implement • Large amount of infrastructure required • SVE and ex-situ vapor treatment required; must meet air emission ARARs • Ex-situ groundwater treatment required with re-injection into BFS and Gage via Groundwater Remedy Treatment System; groundwater RD will need to account for increased re-injection flow • Requires skilled field operators • High level of maintenance required including boiler maintenance, water conditioning, and brine disposal • High energy requirement; large carbon footprint (46 million pounds of greenhouse gases); 10x higher than RA 4; does not meet global warming TBCs • Lack of steam vendors; some vendors have abandoned technology as not commercial; only one vendor with sufficient resources to potentially implement RA • Very infrequently implemented as compared with other thermal remediation technologies • ICs will be required as part of soil and groundwater remedies • Hydraulic containment required for groundwater remedy	• High	Yes

TABLE 5.2 (continued)
Intermediate Screening of DNAPL Remedial Alternatives

Remedial Alternative	Remedial Technology Components	Technical Effectiveness	Implementability	Relative Cost	Retain for Detailed Evaluation? (Yes/No)
RA 5b	• Steam Injection with Hot Floor, Entire DNAPL-Impacted Area • SVE, Unsaturated Zone • Institutional Controls • Hydraulic Containment	• Potentially effective (but highly uncertain) • Highest level of remedial action considered in FS • Includes treatment outside of focused area, where 40% of the DNAPL mass is located over 84% of the target area; treatment area is 6x larger than focused treatment area • Will not reduce DNAPL mobility over RAs 4 or 5a • Would be one of the largest steam injection projects ever implemented and likely the most complex • Greater potential for non-uniform heating, formation of "cold spots", and downward migration • Residual DNAPL, which was previously immobile, has the potential to be mobilized and may not be effectively recovered over large treatment area • Hot floor in underlying BFS would be required but effectiveness over large treatment area is reduced and unprecedented • Steam injection has not been field pilot tested at Site • Steam injection is dependent on soil permeability; steam will preferentially flow through high permeability soil layers; not well-suited to low permeability and heterogeneous UBA; was not assembled into formal RA at nearby Del Amo Site for this reason • Has never been applied to DNAPL composed of primarily MCB or DDT; MCB boiling point is higher than most other VOCs • Will mobilize and concentrate DNAPL at steam front; increased potential for lateral spreading and downward migration • Risk of spreading contaminants under industrial building at former Boeing Realty Corporation property • Steam condensate will become contaminated and may migrate downward if not effectively recovered • SVE will reduce mass of VOCs/DNAPL in the unsaturated zone, increase protectiveness of groundwater, and control VOC migration in soil gas • ICs will protect human health by controlling contaminant exposure pathways • Required duration of hydraulic containment (3,600 years) not significantly reduced by highest cost full-scale RA; no cost-benefit	• Difficult to implement • Large number of wells, up to 184, would be required and would generate a significant amount of waste • Large amount of infrastructure required • SVE and ex-situ vapor treatment required; must meet air emission ARARs • Ex-situ groundwater treatment (200 gpm) required with re-injection into BFS and Gage via Groundwater Remedy Treatment System; groundwater RD will need to account for increased re-injection flow • Requires skilled field operators • High level of maintenance required including boiler maintenance, water conditioning, and brine disposal • Very high energy requirement; largest carbon footprint of all RAs (46 million pounds of greenhouse gases), 4x higher than RA 5a and 40x higher than RA 4; does not meet global warming TBCs • Lack of steam vendors; some vendors have abandoned technology as not commercial; only one vendor with sufficient resources to potentially implement RA • Very infrequently implemented as compared with other thermal remediation technologies	• Very High • Would be largest privately-funded thermal remedy ever implemented; prohibitive financial burden to Montrose	No

TABLE 5.2 (continued)
Intermediate Screening of DNAPL Remedial Alternatives

Remedial Alternative	Remedial Technology Components	Technical Effectiveness	Implementability	Relative Cost	Retain for Detailed Evaluation? (Yes/No)
RA 6a	• ERH without Hot Floor, Focused Treatment Area • SVE, Unsaturated Zone • Institutional Controls • Hydraulic Containment	• Potentially effective (but uncertain) • ERH may reduce DNAPL mass within a focused treatment area containing mobile DNAPL; 60% of the mass is located within 16% of the DNAPL-impacted area • Has not been bench or field pilot tested at Site • More applicable to low permeability UBA than steam injection • Water influx will cool treatment area extending duration of remedy • Variations in soil resistivity can result in "cold spots" • May have difficulty heating entire 45-foot thickness; not typically applied to treatment intervals greater than approximately 30 feet • Relies exclusively on contaminant volatilization (no displacement mechanism); higher well density than steam injection reduces potential for contaminant spreading; although unrecovered vapors may re-condense in another area of the UBA • No steam front; reduced potential for downward mobilization as compared with steam injection • A hot floor may not be required for ERH RA • Has never been applied to site with DNAPL composed of MCB or DDT; 96°C co-boiling point for Montrose DNAPL is one of highest and approaching upper limit of ERH capability (i.e., 100°C) • ERH identified as a candidate at Del Amo Site for LNAPL; benzene co-boiling and boiling points are 69°C and 80°C • SVE will reduce mass of VOCs/DNAPL in the unsaturated zone, increase protectiveness of groundwater, and control VOC migration in soil gas • ICs will protect human health by controlling contaminant exposure pathways • Hydraulic containment will prevent migration of dissolved-phase contaminants and reduce DNAPL mass in the long-term by dissolution; required duration (4,400 years) not significantly reduced by high cost source area RA	• Difficult to implement • Large amount of infrastructure required • Would require installation of 87 electrode locations and management of waste • Three qualified vendors are available to implement ERH • ERH is more frequently implemented than steam injection • High energy RA; carbon footprint is large (14 million pounds of greenhouse gases) ; does not meet global warming TBCs; is 70% lower than steam injection RA 5a • SVE and ex-situ vapor treatment required; must meet air emissions ARARs • Ex-situ groundwater treatment required with re-injection into BFS and Gage via Groundwater Remedy Treatment System; groundwater RD will need to account for increased re-injection flow • Requires skilled field operators • High level of maintenance required • ICs will be required as part of soil and groundwater remedies • Hydraulic containment required for groundwater remedy	• High	Yes

TABLE 5.2 (continued)
Intermediate Screening of DNAPL Remedial Alternatives

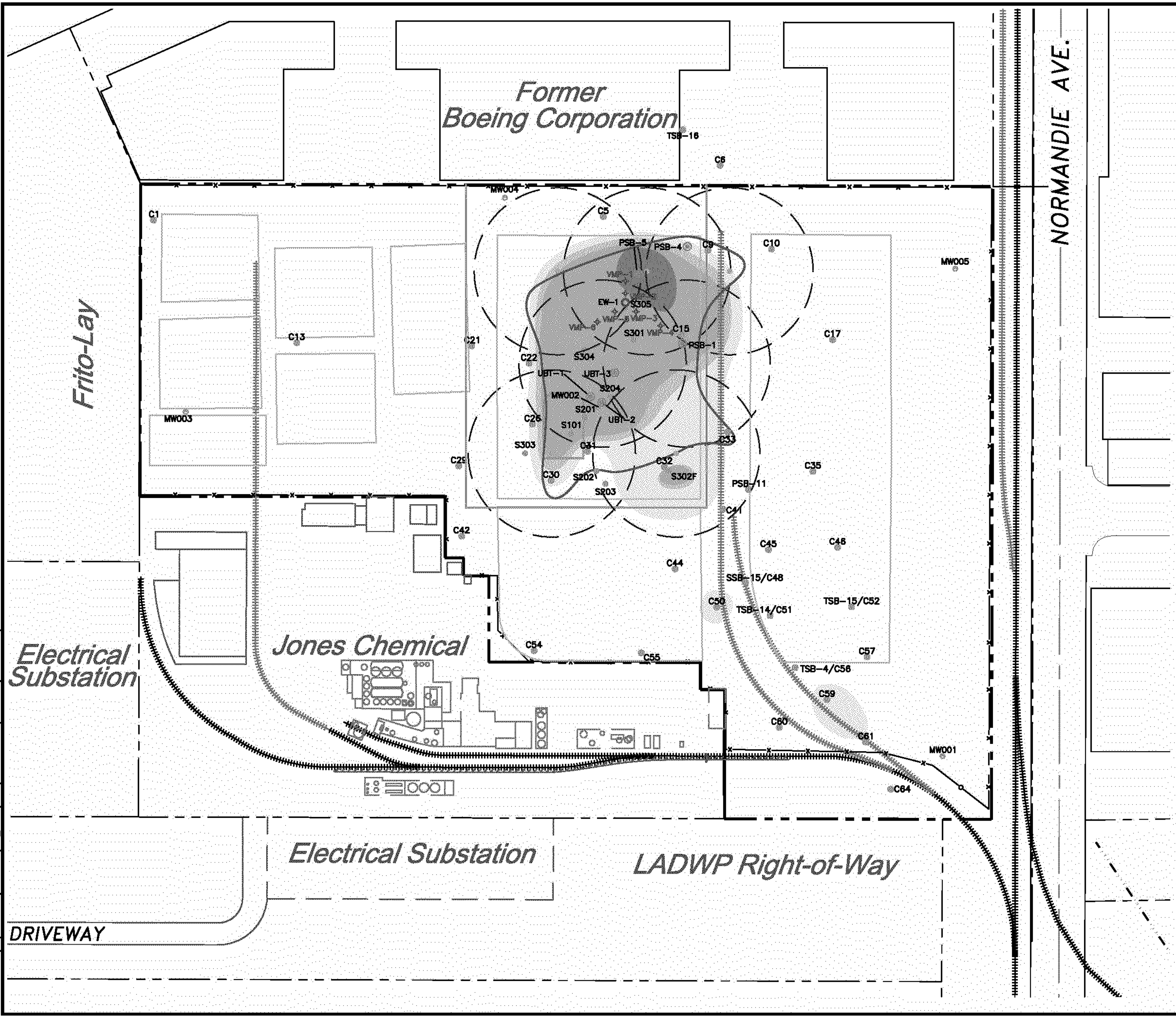
Remedial Alternative	Remedial Technology Components	Technical Effectiveness	Implementability	Relative Cost	Retain for Detailed Evaluation? (Yes/No)
RA 6b	• ERH without Hot Floor, Entire DNAPL-Impacted Area • SVE, Unsaturated Zone • Institutional Controls • Hydraulic Containment	• Potentially effective (but uncertain) • Highest level of remedial action considered in FS • Includes treatment outside of focused area, where 40% of the DNAPL mass is located over 84% of the target area; treatment area is 6x larger than focused treatment area • Will not reduce DNAPL mobility over RAs 4, or 5a • Would be the largest ERH project ever implemented and likely the most complex; there are no comparable sites • Greater potential for non-uniform heating; variations in soil resistivity can result in "cold spots" • Residual DNAPL, which was previously immobile, has the potential to be mobilized and may not be effectively recovered over large treatment area • Water influx will cool treatment area extending duration of remedy • May have difficulty heating entire 45-foot thickness; not typically applied to treatment intervals greater than approximately 30 feet • Increased potential for downward migration to occur as a result of drilling large number of electrodes, wells, and monitoring points (729) • Relies exclusively on contaminant volatilization (no displacement mechanism); higher well density than steam injection reduces potential for contaminant spreading; although unrecovered vapors may re-condense in another area of the UBA • A hot floor may not be required for ERH RA • Has never been applied to site with DNAPL composed of MCB or DDT; 96°C co-boiling point for Montrose DNAPL is one of highest and approaching upper limit of ERH capability (i.e., 100°C) • ERH identified as a candidate at Del Amo Site for LNAPL; benzene co-boiling and boiling points are 69°C and 80°C • SVE will reduce mass of VOCs/DNAPL in the unsaturated zone, increase protectiveness of groundwater, and control VOC migration in soil gas • ICs will protect human health by controlling contaminant exposure pathways • Required duration of hydraulic containment (3,600 years) not significantly reduced by highest cost full-scale RA; no cost-benefit	• Difficult to implement • Large amount of infrastructure required • Would require a significant number of electrodes, multiphase extraction wells, and temperature monitoring points (729), generating a significant amount of waste • Three qualified vendors are available to implement ERH • ERH is more frequently implemented than steam injection • Exceptionally high energy RA; carbon footprint is very large (58 million pounds of greenhouse gases) and does not meet global warming TBCs; 4x higher than RA 6a and 14x higher than RA 4 • SVE and ex-situ vapor treatment required; must meet air emission ARARs • Ex-situ groundwater treatment required with re-injection into BFS and Gage via Groundwater Remedy Treatment System; groundwater RD will need to account for increased re-injection flow • Requires skilled field operators • High level of maintenance required • ICs will be required as part of soil and groundwater remedies • Hydraulic containment required for groundwater remedy	• Very High • Would be largest privately-funded thermal remedy ever implemented; prohibitive financial burden to Montrose	No

TABLE 5.2 (continued)
Intermediate Screening of DNAPL Remedial Alternatives

Notes:

RA = Remedial alternative
ICs = Institutional controls
HD = Hydraulic displacement
DNAPL = Dense Non-Aqueous Phase Liquid
DDT = Dichlorodiphenyltrichloroethane
MCB = Monochlorobenzene
UBA = Upper Bellflower Aquitard
BFS = Bellflower Sand
SVE = Soil vapor extraction
VOCs = Volatile organic compounds
ERH = Electrical resistance heating
ROD = Record of Decision
RD = Remedial design
ARARs = Appropriate Relevant and Applicable Requirements
°C = Degrees Centrigrade
TBCs = Criteria *To Be Considered* in this DNAPL FS

FIGURES



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- Soil Boring Location
- Monitoring Well Location
- Maximum MCB Isoconcentration in Soil Contour Interval 10–100 mg/kg
- Maximum MCB Isoconcentration in Soil Contour Interval 100–1000 mg/kg
- Maximum MCB Isoconcentration in Soil Contour Interval 1000–10,000 mg/kg
- Maximum MCB Isoconcentration in Soil Contour Interval >10,000 mg/kg
- DNAPL Present
- DNAPL Present in Vadose Zone Boring Location
- SVE Pilot Test Well Location
- Pilot Test Monitoring Point Location
- Radius of Influence (103 Ft.) Palos Verdes Sands (Number of Wells = 7)

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

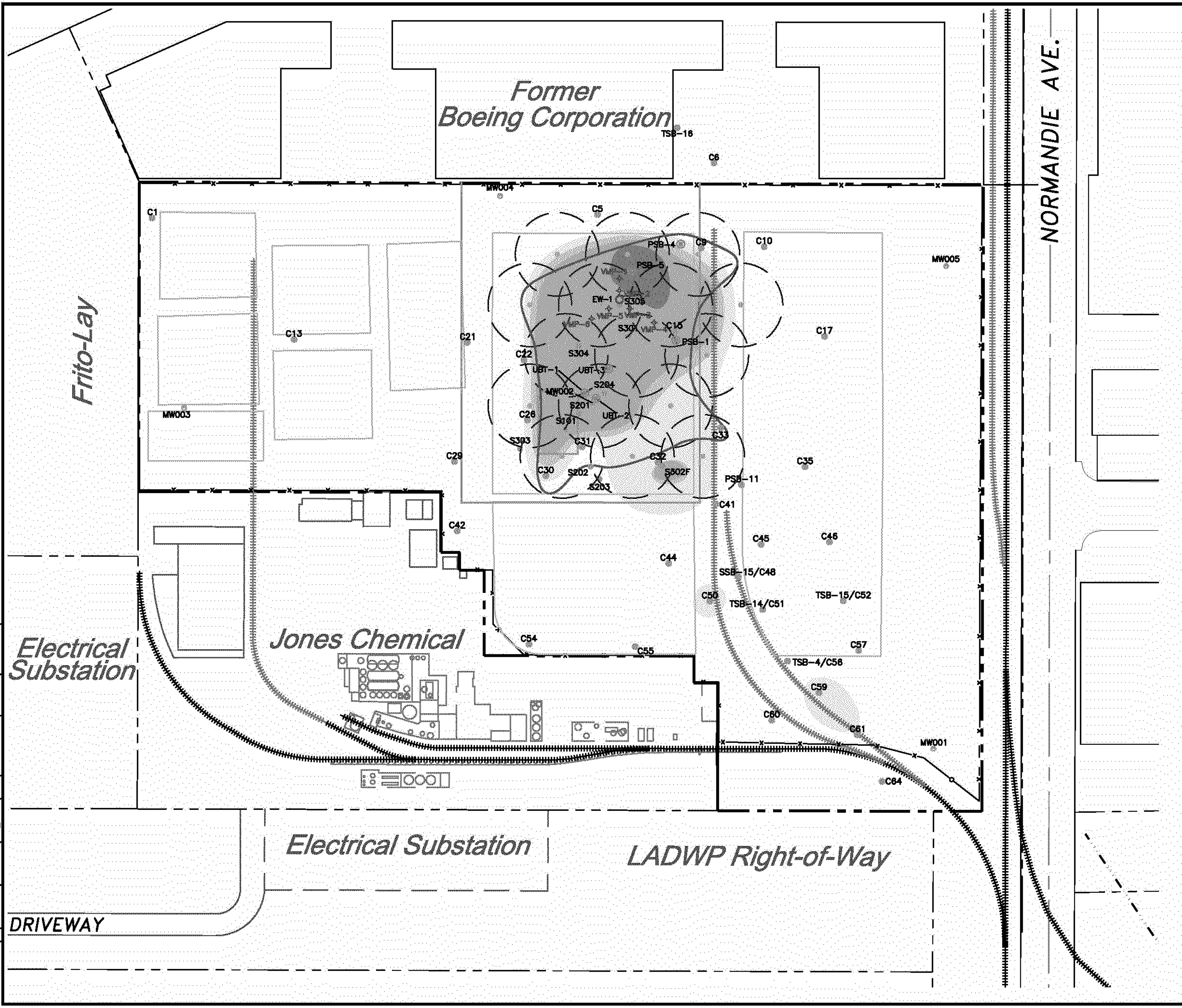
NORTH

0 60 120 FEET

SCALE: 1"= 120'

Montrose Chemical Corporation	Conceptual SVE Wells Palos Verdes Sands, Radius of Influence 103 Feet		
Date: 04-09	Montrose Superfund Site		Figure
Project No. 103960	EARTH TECH	AECOM	5.1

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2008\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.1.041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- Soil Boring Location
- Monitoring Well Location
- Maximum MCB Isoconcentration in Soil Contour Interval 10–100 mg/kg
- Maximum MCB Isoconcentration in Soil Contour Interval 100–1000 mg/kg
- Maximum MCB Isoconcentration in Soil Contour Interval 1000–10,000 mg/kg
- Maximum MCB Isoconcentration in Soil Contour Interval >10,000 mg/kg
- DNAPL Present
- DNAPL Present in Vadose Zone Boring Location
- SVE Pilot Test Well Location
- Pilot Test Monitoring Point Location
- Radius of Influence (52 Ft.) Unsaturated Upper Bellflower Aquitard (Number of Wells = 16)

References:

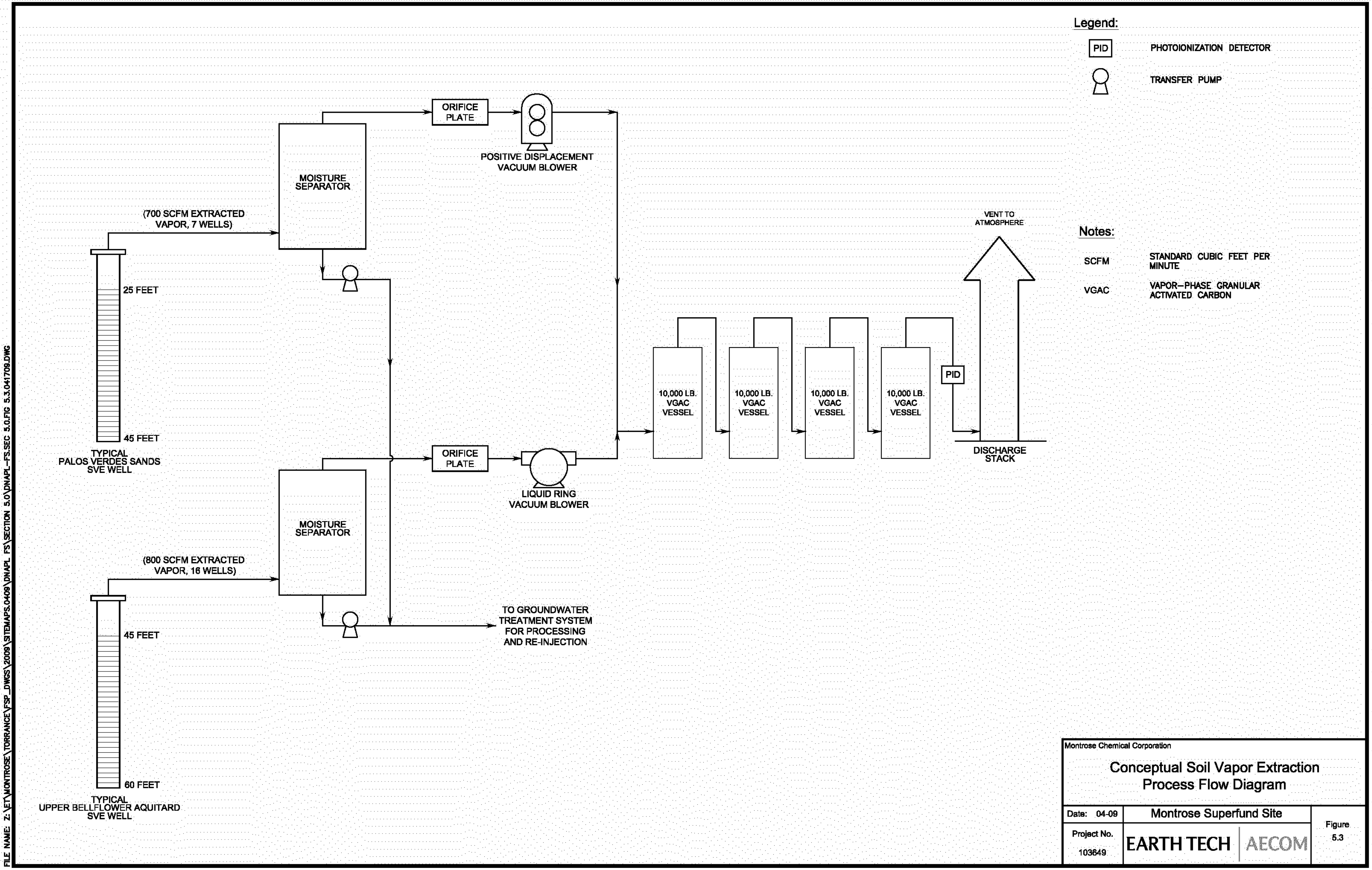
1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin–Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2004a; Earth Tech, 2007; Earth Tech, 2008c; EPA, 1998; H+A, 2004b; H+A, 2006a; H+A, 2008b

Montrose Chemical Corporation

Conceptual SVE Wells Upper Bellflower Aquitard, Radius of Influence 52 Feet

Date: 04-09	Montrose Superfund Site	Figure 5.2
Project No. 103960	EARTH TECH / AECOM	

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.2.041709.DWG

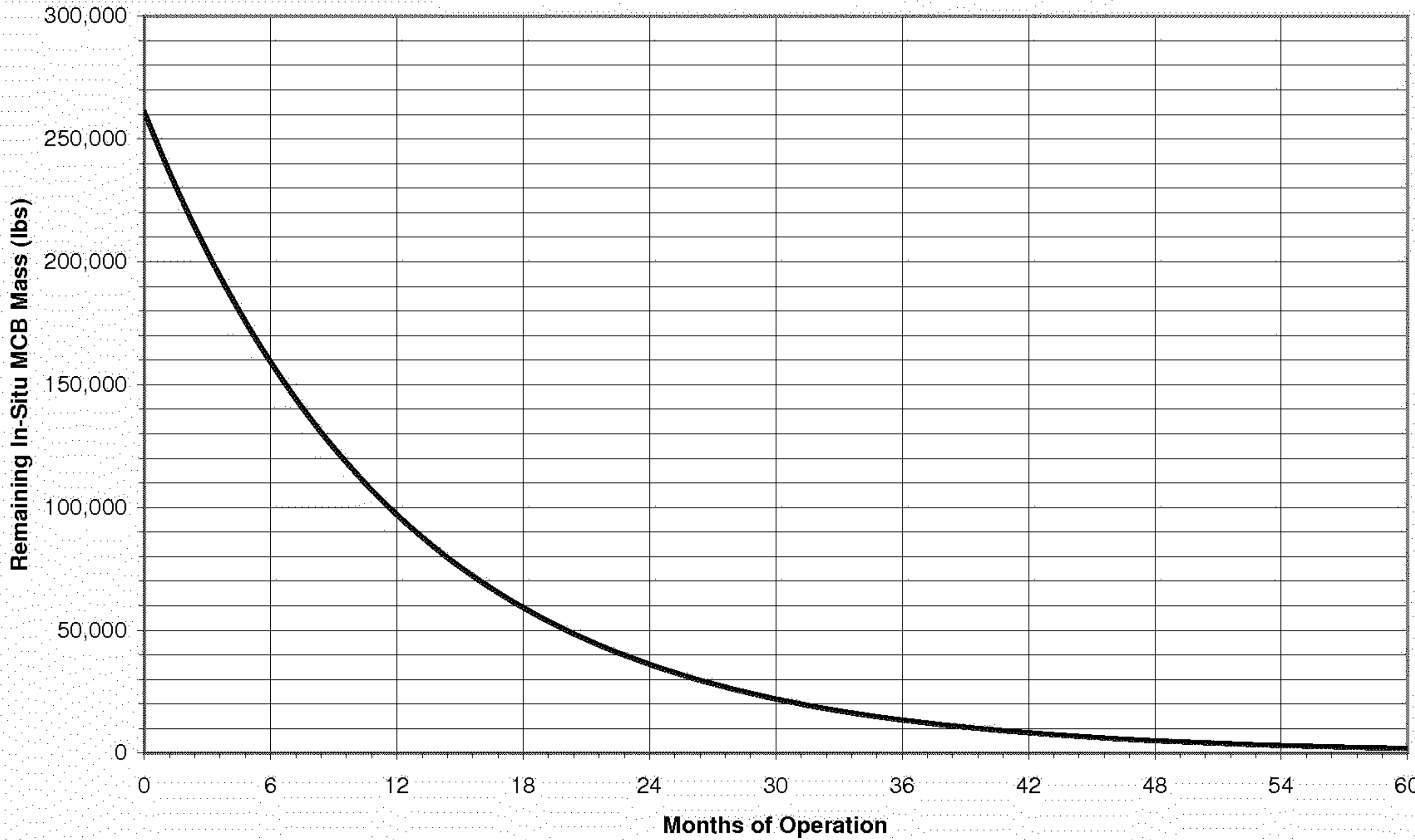


Montrose Chemical Corporation

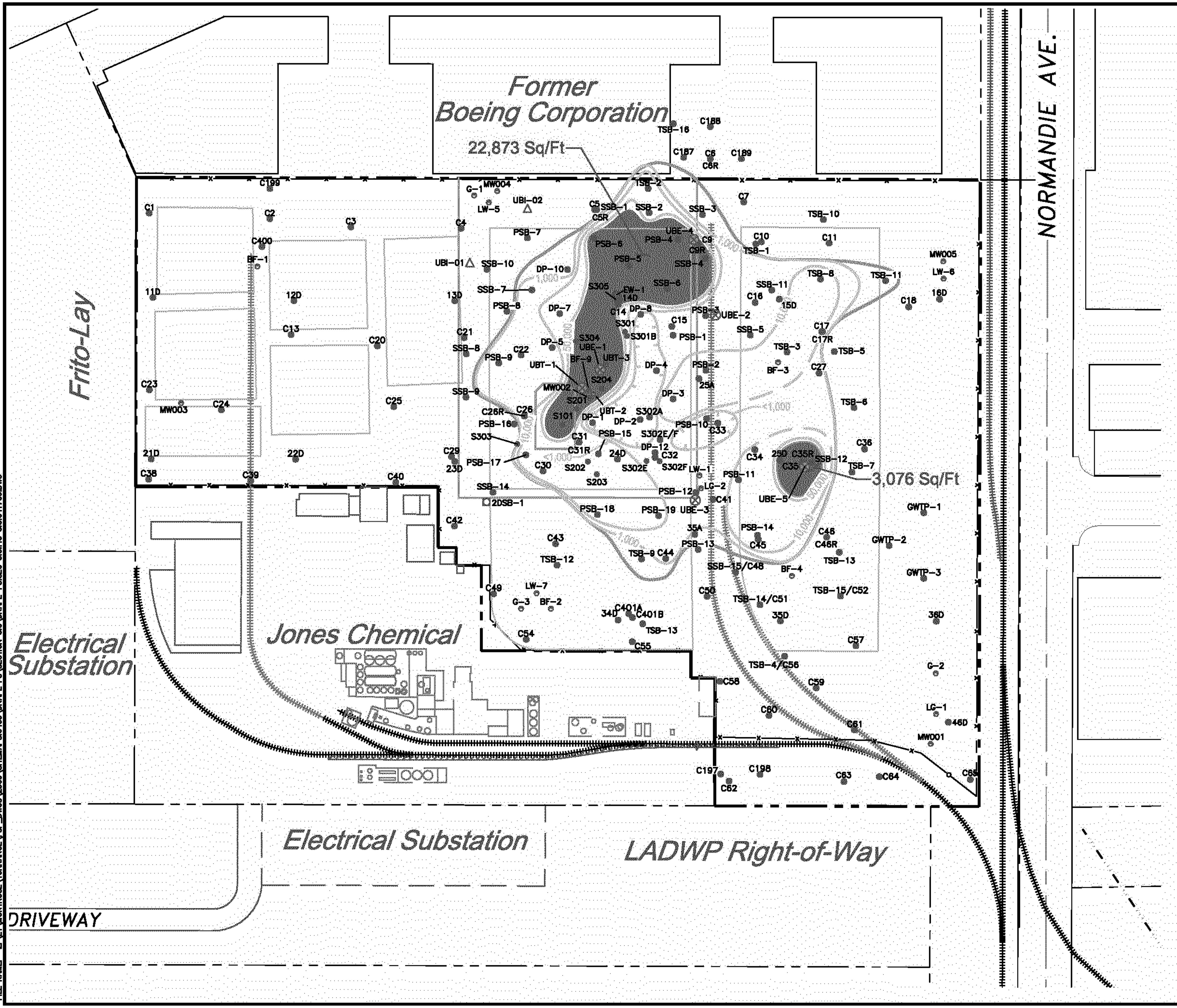
Conceptual Soil Vapor Extraction Process Flow Diagram

Date: 04-09	Montrose Superfund Site	Figure 5.3
Project No. 103649	EARTH TECH AECOM	

Figure 5.4
Example MCB Mass Decline Curve
Implementation of SVE in Unsaturated Zone (25-60 feet bgs)
Montrose Superfund Site



Note: Data was generated using a first order decay



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- EW-1 — SVE Well Location
- UBI-01 — Injection Well Location
- 2DSB-1 — 2-Dimensional Bench Scale Test Soil Boring, Saturated Upper Bellflower Aquitard
- Entire DNAPL Impacted Area
- 1,000 — DNAPL Isoconcentration in mg/kg (MCB + Total DDT)
- 10,000 — DNAPL Isoconcentration in mg/kg (MCB + Total DDT)
- 50,000 — DNAPL Isoconcentration in mg/kg (MCB + Total DDT)
- Estimated Extent of Mobile DNAPL Contiguous Area >53,000 mg/kg Total Area: 25,949 Sq. Ft.

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2008b

NORTH

0 60 120 FEET

SCALE: 1" = 120'

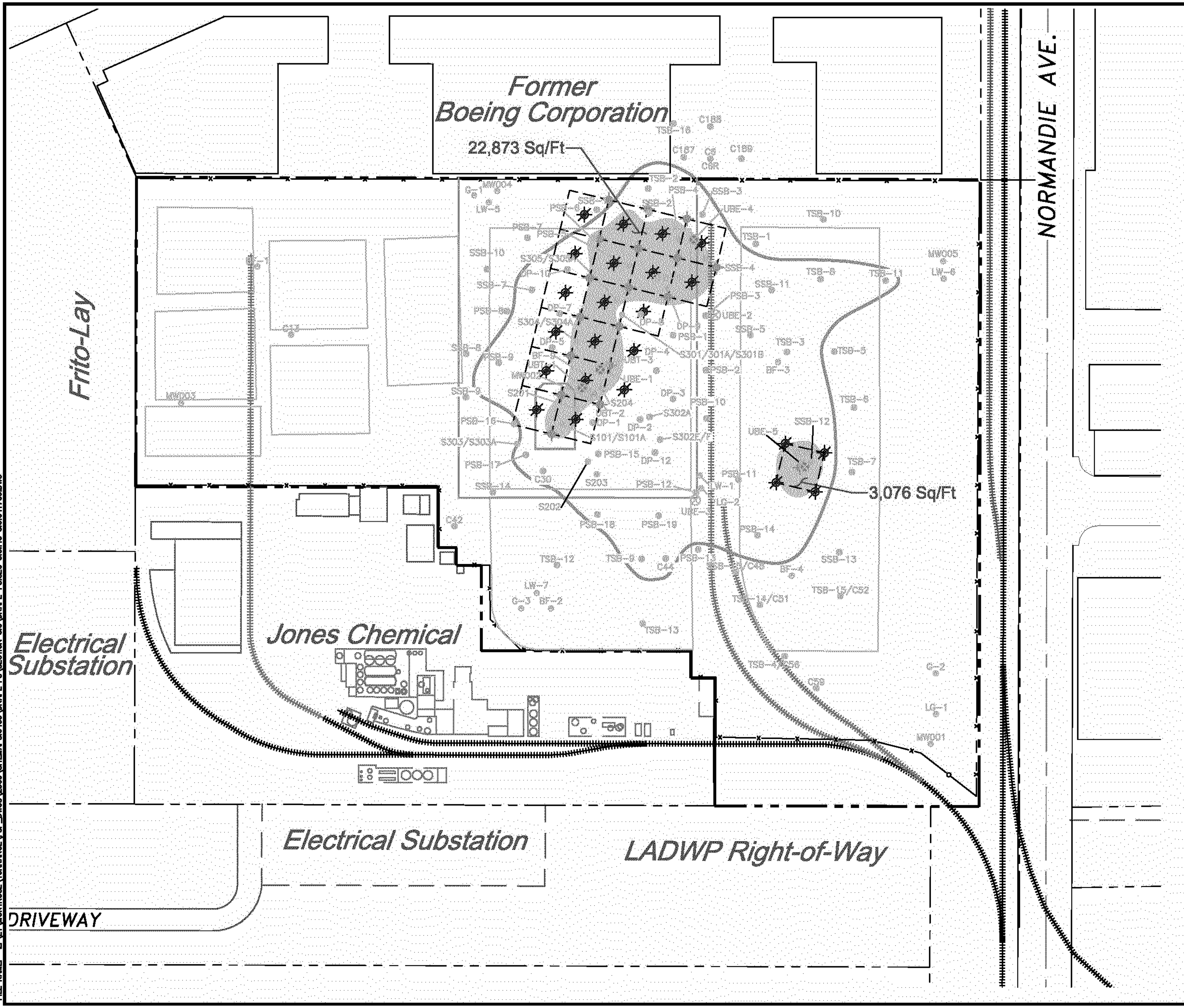
Montrose Chemical Corporation

Estimated Extent of Mobile DNAPL in Saturated UBA

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	5.5

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.5.041709.DWG

BOE-C6-0059884



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- Entire DNAPL Impacted Area
- Estimated Extent of Mobile DNAPL Contiguous Area >53,000 mg/kg Total Area: 25,949 Sq. Ft.
- Injection Well Location (23)
- Extraction Well Location (18)

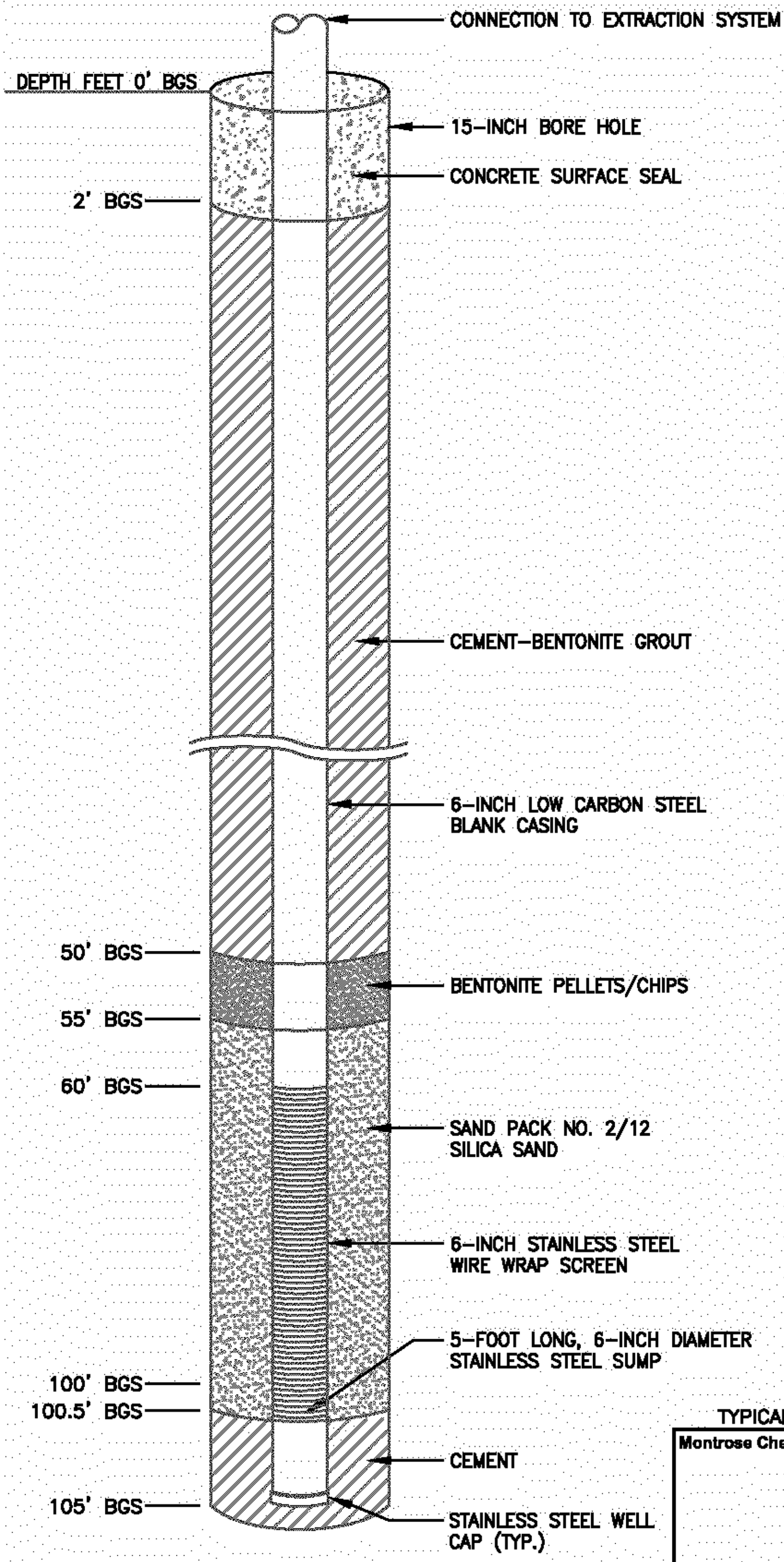
References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2008b

Montrose Chemical Corporation		
UBA Conceptual Hydraulic Displacement Well Pattern - 50 Foot Spacing		
Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	5.6

FILE NAME: Z:\VET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL_FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.6.041709.DWG

BOE-C6-0059885



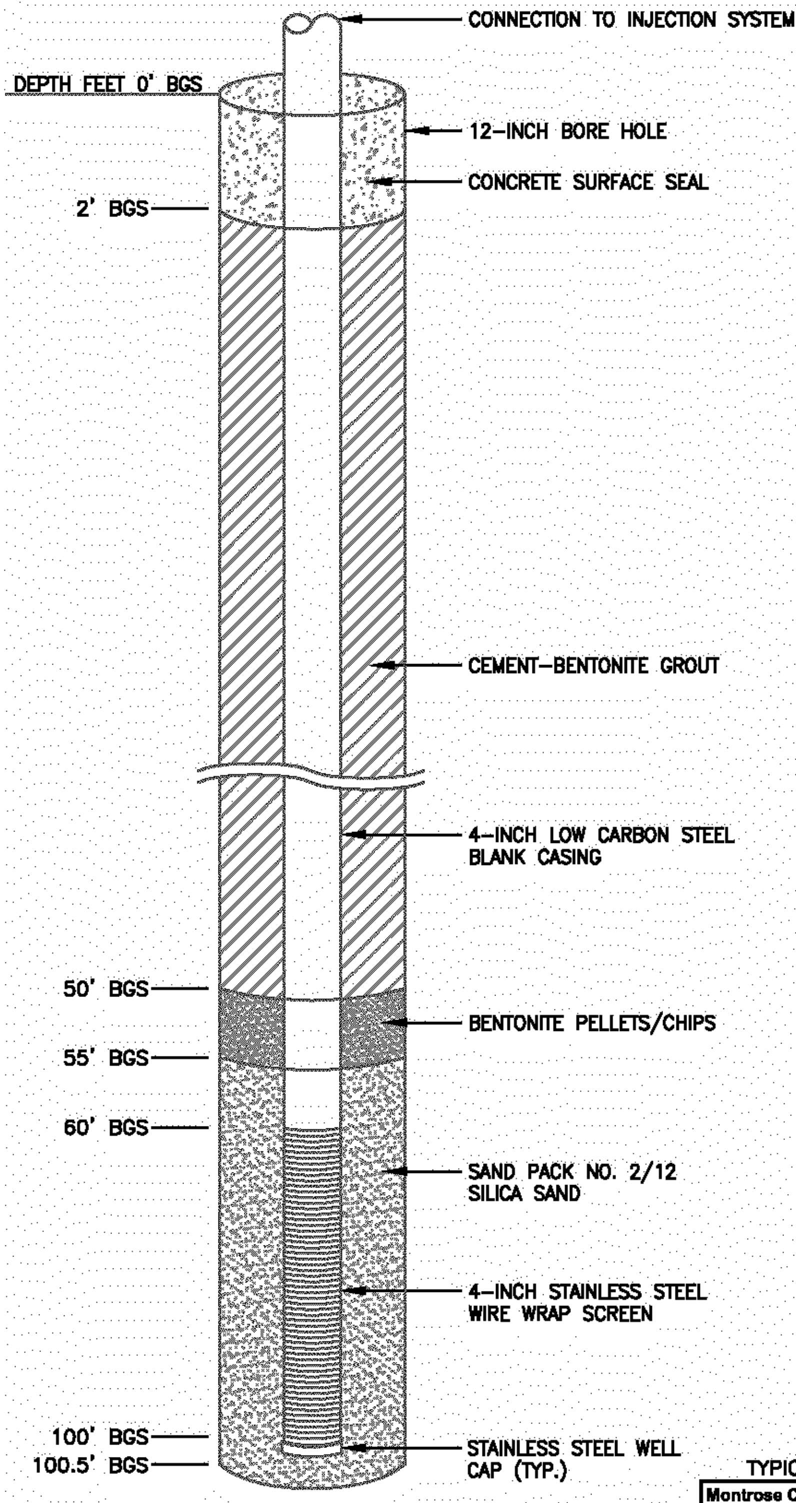
TYPICAL WELL CONSTRUCTION DIAGRAM – NOT TO SCALE

Montrose Chemical Corporation

DNAPL Extraction Well Construction Diagram

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	5.7

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL_FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.7.041709.DWG



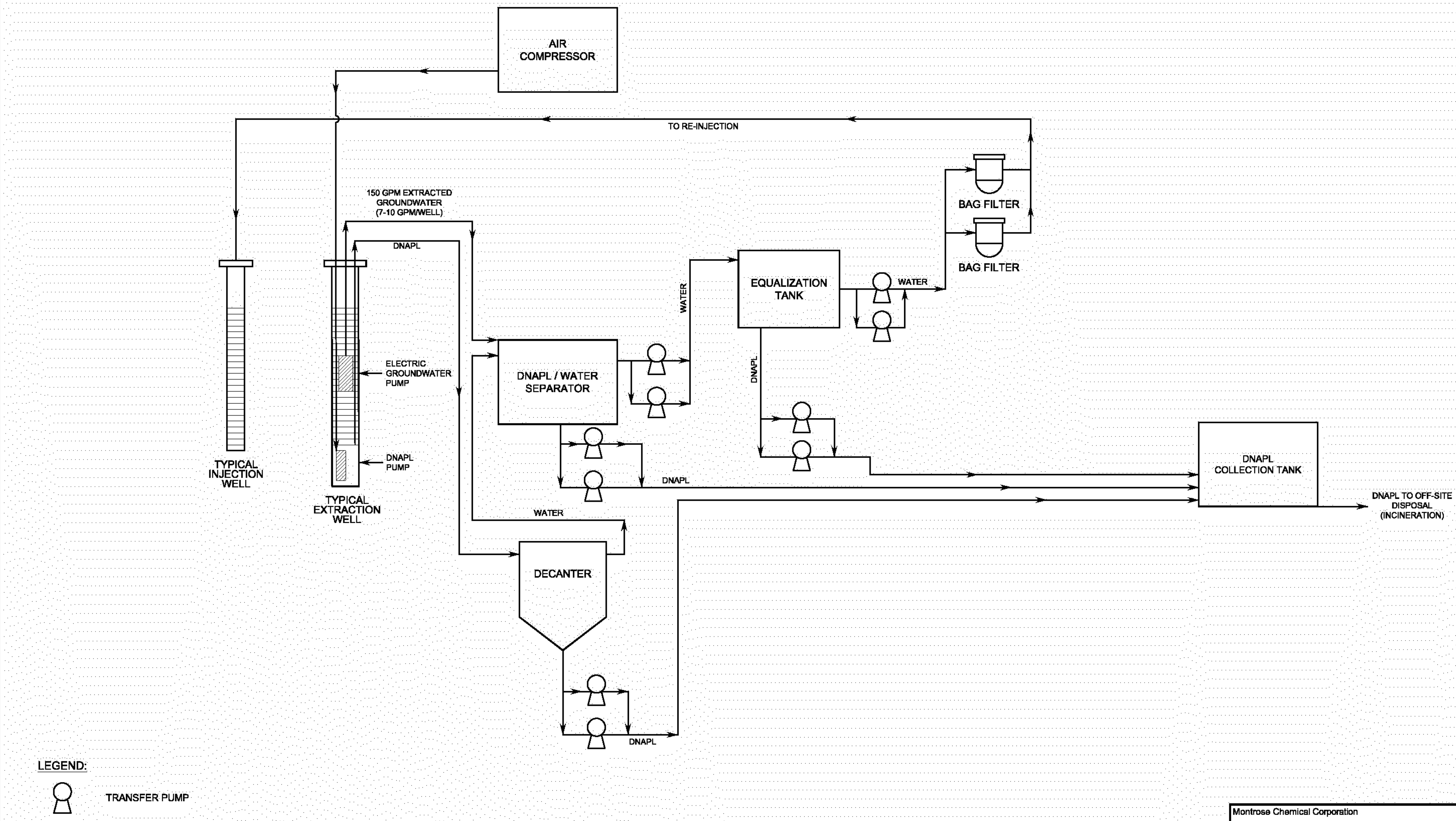
TYPICAL WELL CONSTRUCTION DIAGRAM – NOT TO SCALE

Montrose Chemical Corporation

Groundwater Injection Well Construction Diagram

Date: 04-09	Montrose Superfund Site	Figure 5.8
Project No. 103649	EARTH TECH | AECOM	

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.8.041709.DWG



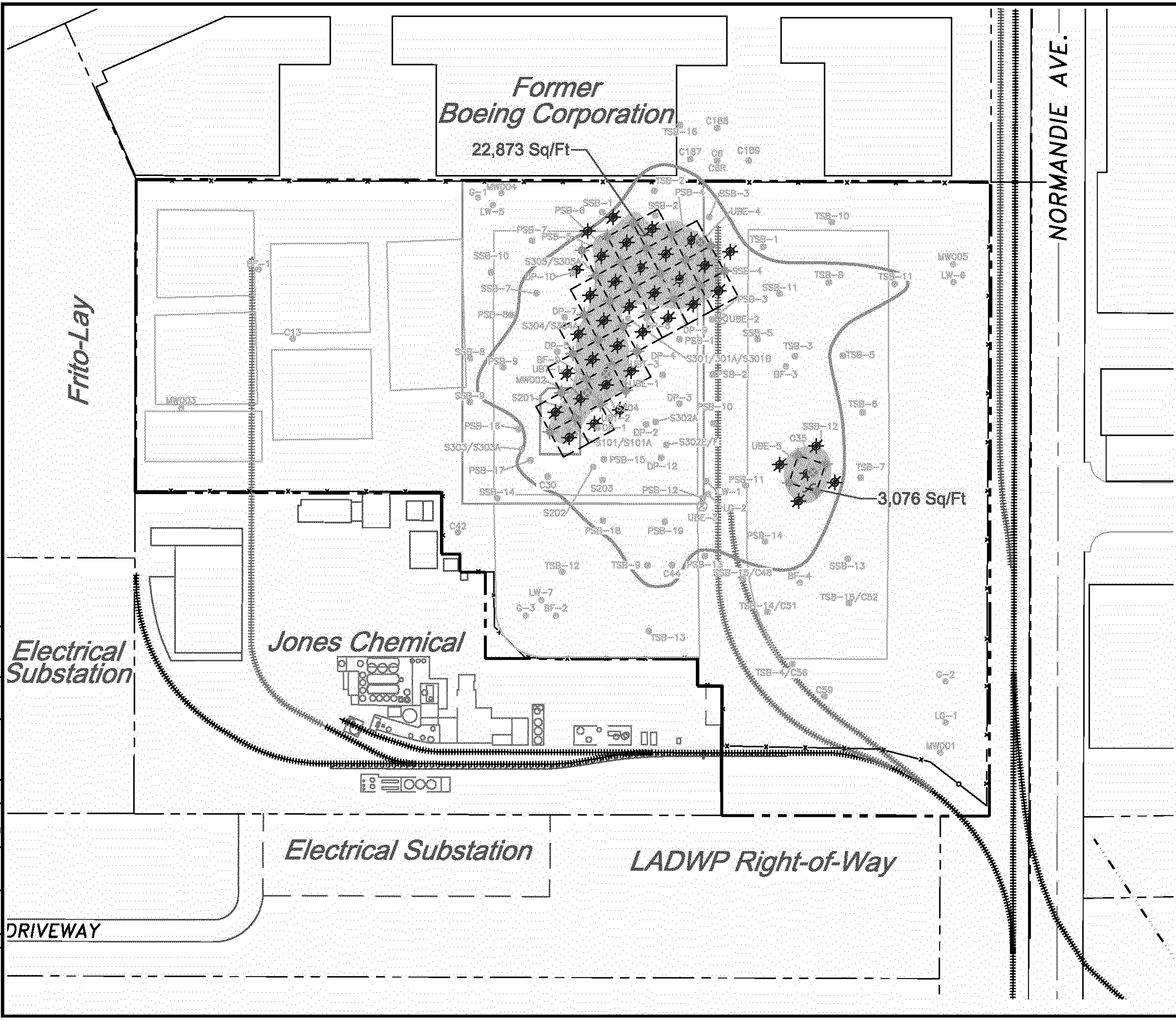
Montrose Chemical Corporation

Conceptual HD Remedy Process Flow Diagram with Untreated Water Re-Injection

Date: 04-09	Montrose Superfund Site		Figure 5.9
Project No. 103649	EARTH TECH	AECOM	

FILE NAME: Z:\et\montrose\torrance\fsp_dwgs\2009\sitemaps.0409\DNAPL FS\Section 5.0\DNAPL-FS.SEC 5.0.FIG 5.9.041709.dwg

BOE-C6-0059888



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- Entire DNAPL Impacted Area
- Estimated Extent of Mobile DNAPL Contiguous Area >53,000 mg/kg Total Area: 25,949 Sq. Ft.
- Injection Well Location (37)
- Extraction Well Location (32)

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2008b

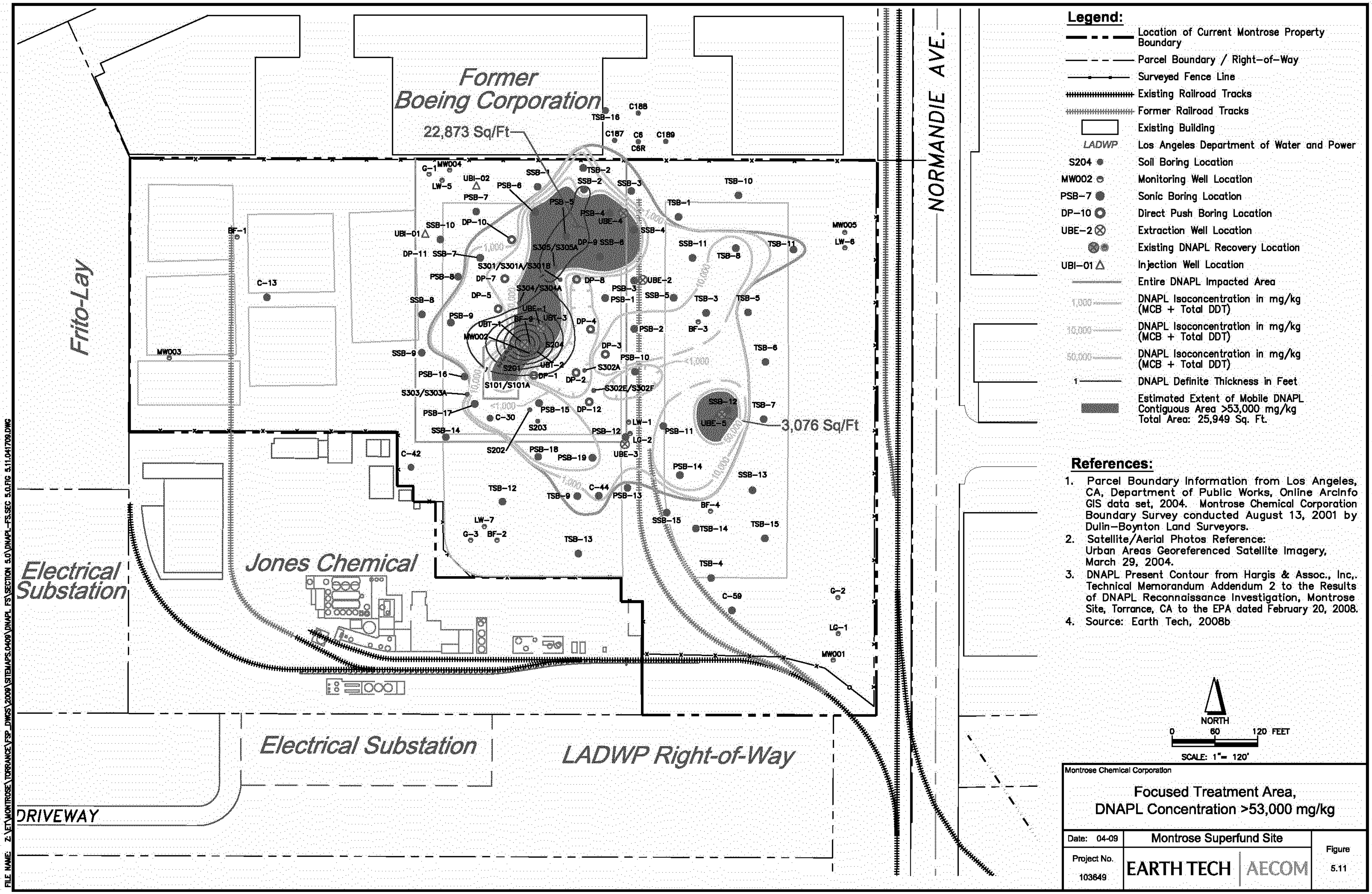
Montrose Chemical Corporation

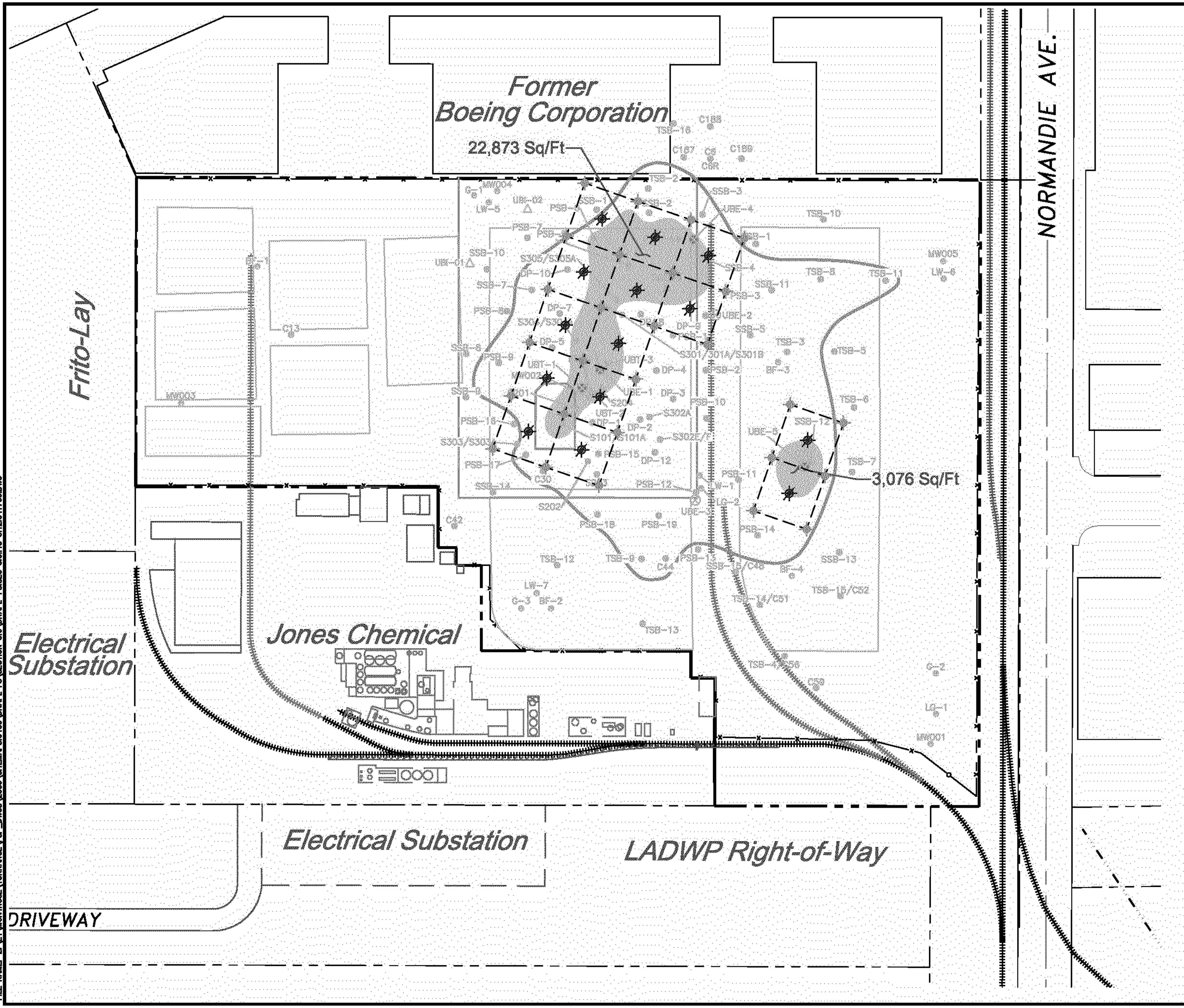
UBA Conceptual Hydraulic Displacement Well Pattern - 25 Foot Spacing

Date: 04-09	Montrose Superfund Site		Figure
Project No. 103649	EARTH TECH	AECOM	5.10

FILE NAME: Z:\VET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.10.041709.DWG

BOE-C6-0059889


Former Boeing Corporation
22,873 Sq/Ft
3,076 Sq/Ft
Frito-Lay
NORMANDIE AVE.
Jones Chemical
Electrical Substation
Electrical Substation
LADWP Right-of-Way
DRIVEWAY
Legend:
Location of Current Montrose Property Boundary
Parcel Boundary / Right-of-Way
Surveyed Fence Line
Existing Railroad Tracks
Former Railroad Tracks
Existing Building
LADWP Los Angeles Department of Water and Power
S204 Soil Boring Location
MW002 Monitoring Well Location
PSB-7 Sonic Boring Location
DP-10 Direct Push Boring Location
UBE-2 Extraction Well Location
Existing DNAPL Recovery Location
UBI-01 Injection Well Location
Entire DNAPL Impacted Area
1,000 DNAPL Isoconcentration in mg/kg (MCB + Total DDT)
10,000 DNAPL Isoconcentration in mg/kg (MCB + Total DDT)
50,000 DNAPL Isoconcentration in mg/kg (MCB + Total DDT)
1 DNAPL Definite Thickness in Feet
Estimated Extent of Mobile DNAPL Contiguous Area >53,000 mg/kg Total Area: 25,949 Sq. Ft.
References:
1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2008b
NORTH
0 60 120 FEET
SCALE: 1"= 120'
Montrose Chemical Corporation
Focused Treatment Area, DNAPL Concentration >53,000 mg/kg
Date: 04-09
Montrose Superfund Site
Project No. 103649
EARTH TECH AECOM
Figure 5.11
FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.11.041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP Los Angeles Department of Water and Power
- S204 Soil Boring Location
- MW002 Monitoring Well Location
- UBE-2 Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 Injection Well Location
- Entire DNAPL Impacted Area
- Estimated Extent of Mobile DNAPL Contiguous Area >53,000 mg/kg Total Area: 25,949 Sq. Ft.
- Steam Injector Well Location (14)
- Multi-Phase Extraction Well Location (27)
- 60-Foot Spacing Between Steam Injection Wells (42-Foot Spacing Between Steam Injection and Extraction Wells)

References:

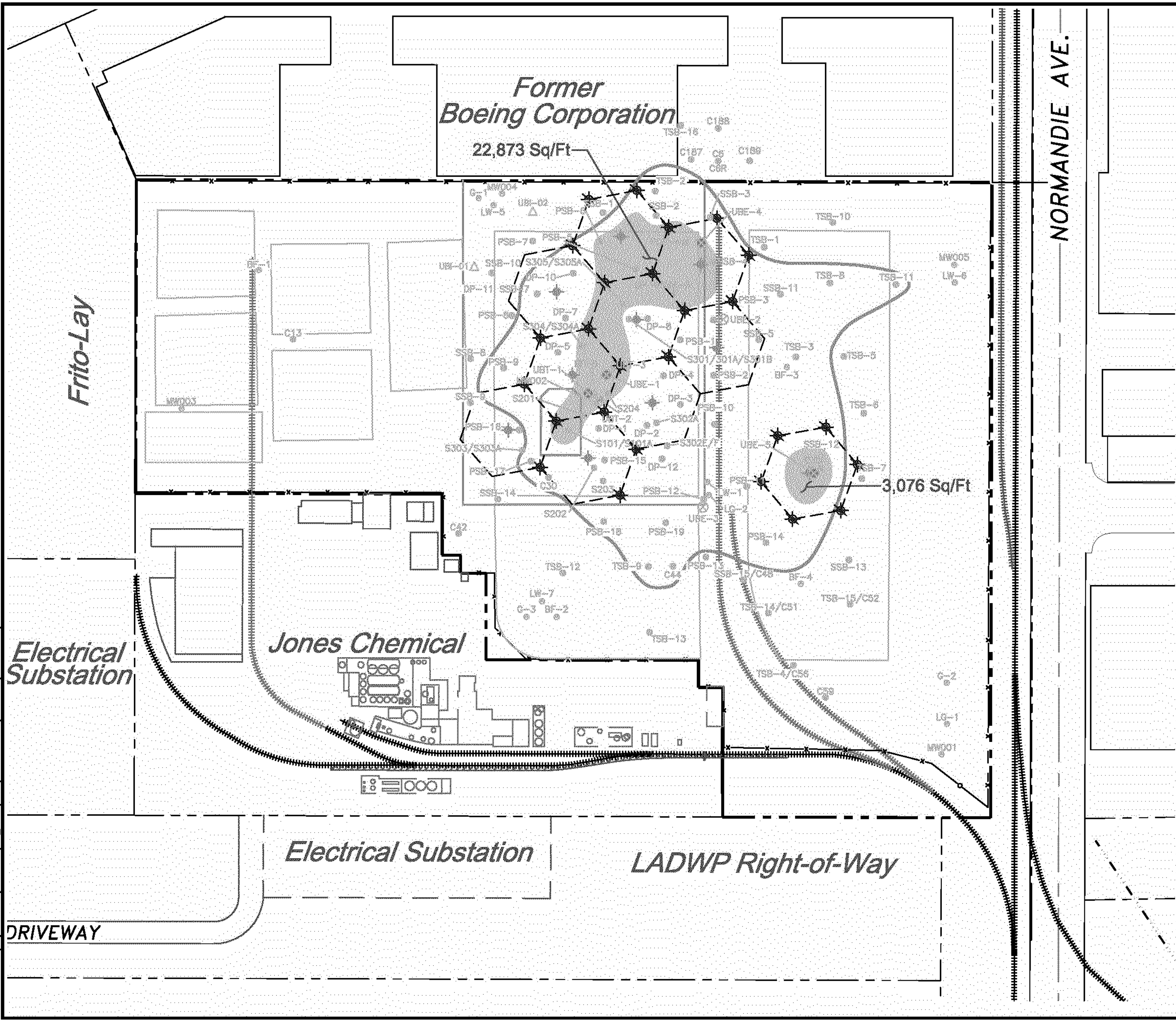
1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2008b and 2008d

Montrose Chemical Corporation

UBA Conceptual Steam Remedy
Well Pattern - 42 Foot Spacing

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	5.12

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2008\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.12.041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- Entire DNAPL Impacted Area
- Estimated Extent of Mobile DNAPL Contiguous Area >53,000 mg/kg Total Area: 25,949 Sq. Ft.
- Steam Injector Well Location (26)
- Multi-Phase Extraction Well Location (10)
- 60-Foot Spacing Between Steam Injection Wells

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2008b and 2008d

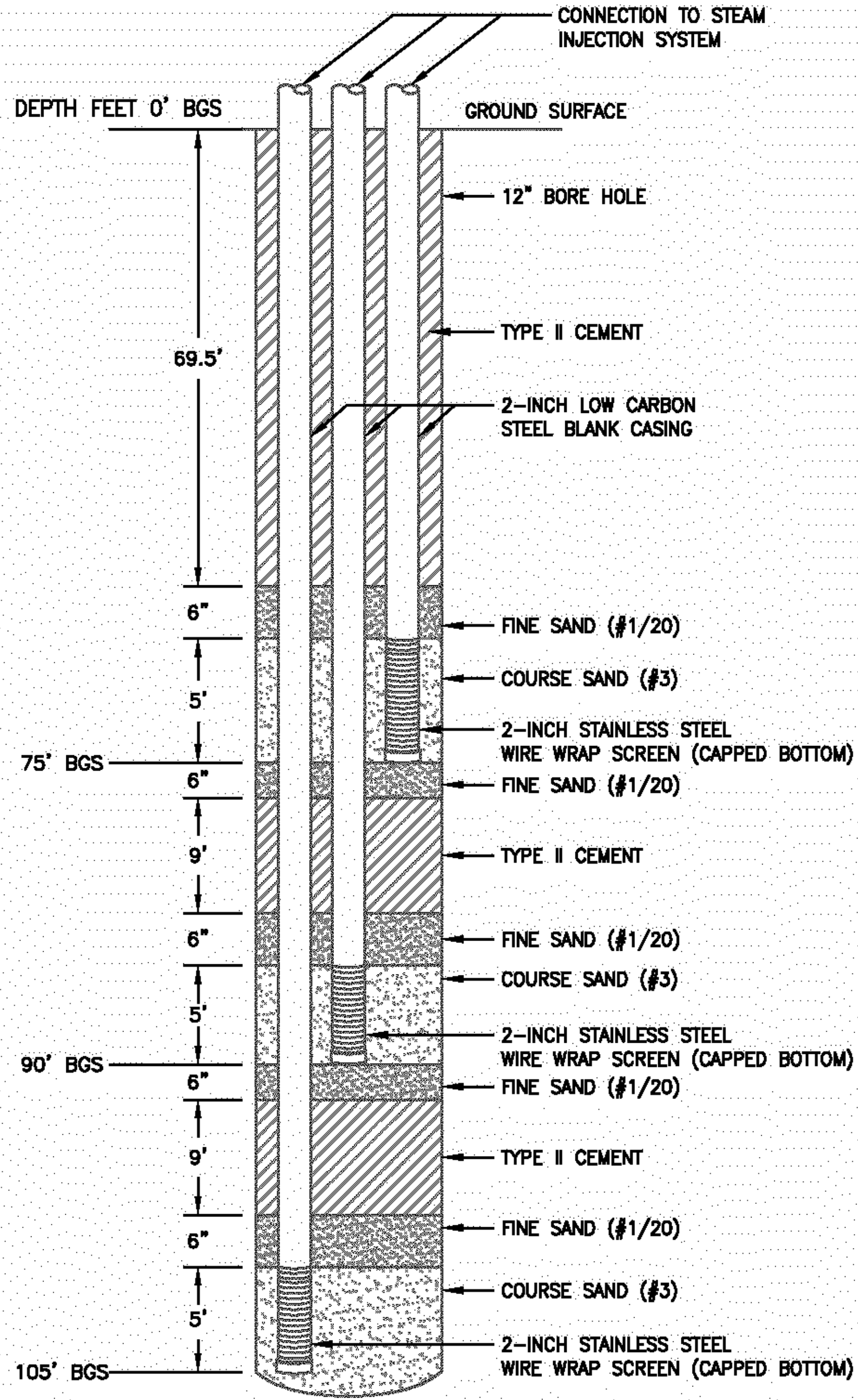
NORTH
0 60 120 FEET
SCALE: 1"= 120'

Montrose Chemical Corporation

UBA Conceptual Steam Remedy
Well Pattern - 60 Foot Spacing

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	5.13

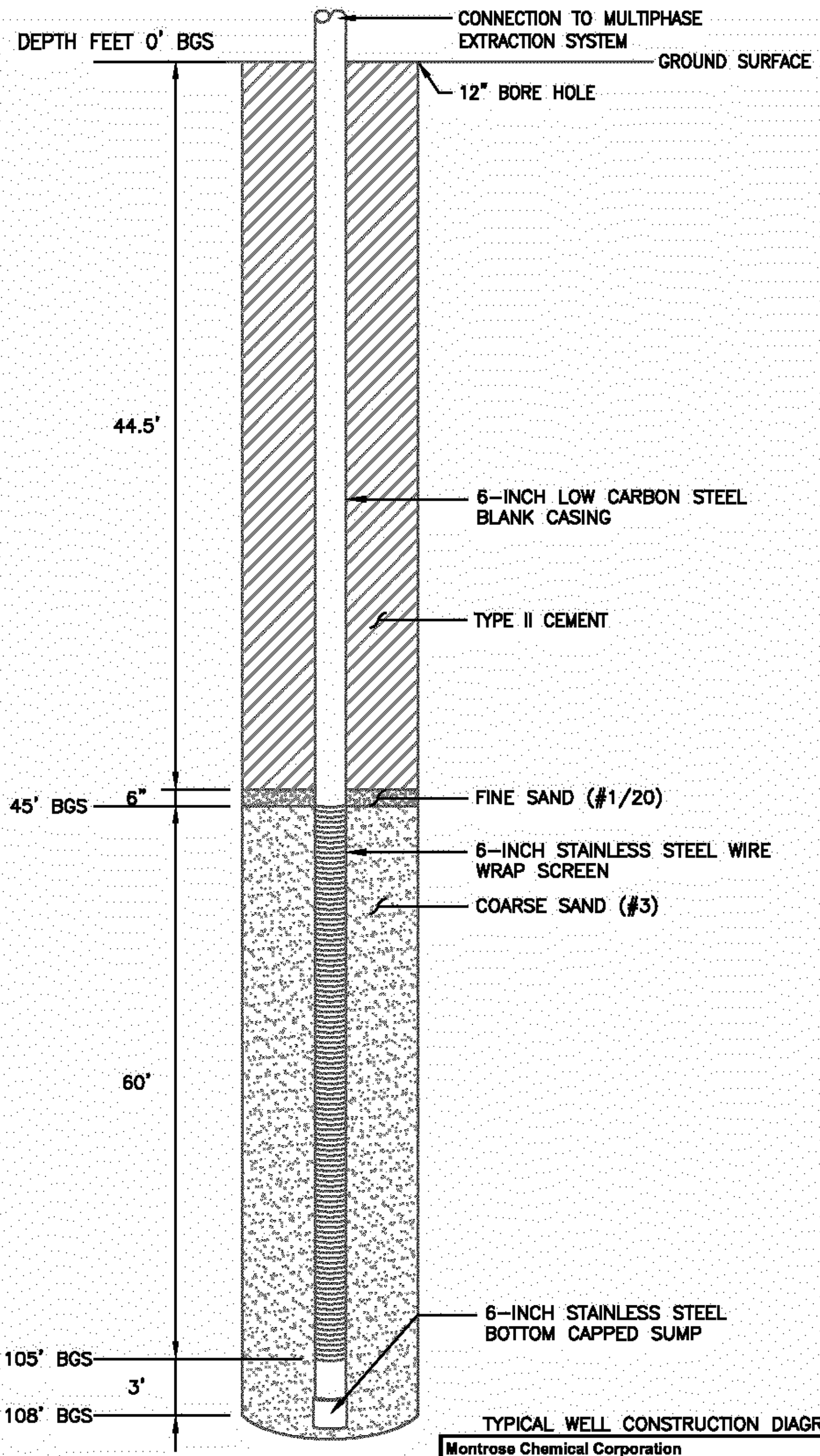
FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.13.041709.DWG



TYPICAL WELL CONSTRUCTION DIAGRAM – NOT TO SCALE

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.14.041709.DWG

Montrose Chemical Corporation		
Upper Bellflower Aquitard Steam Injection Well Construction Diagram		
Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	5.14



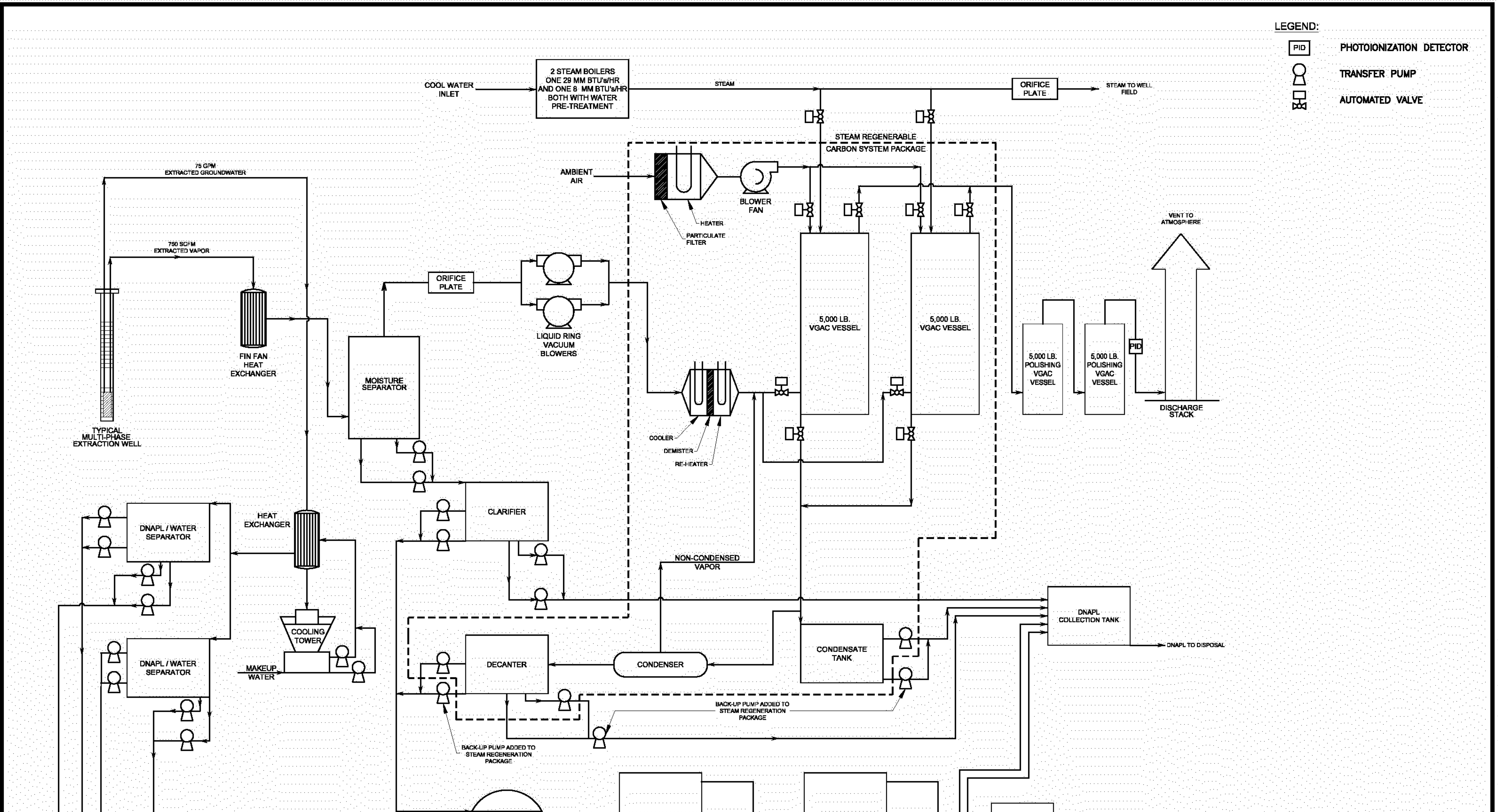
TYPICAL WELL CONSTRUCTION DIAGRAM – NOT TO SCALE

Montrose Chemical Corporation

Upper Bellflower Aquitard
Multi-Phase Extraction
Well Construction Diagram

Date: 04-09	Montrose Chemical Corporation	Figure
Project No. 103649	EARTH TECH | AECOM	5.15

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.15.041709.DWG



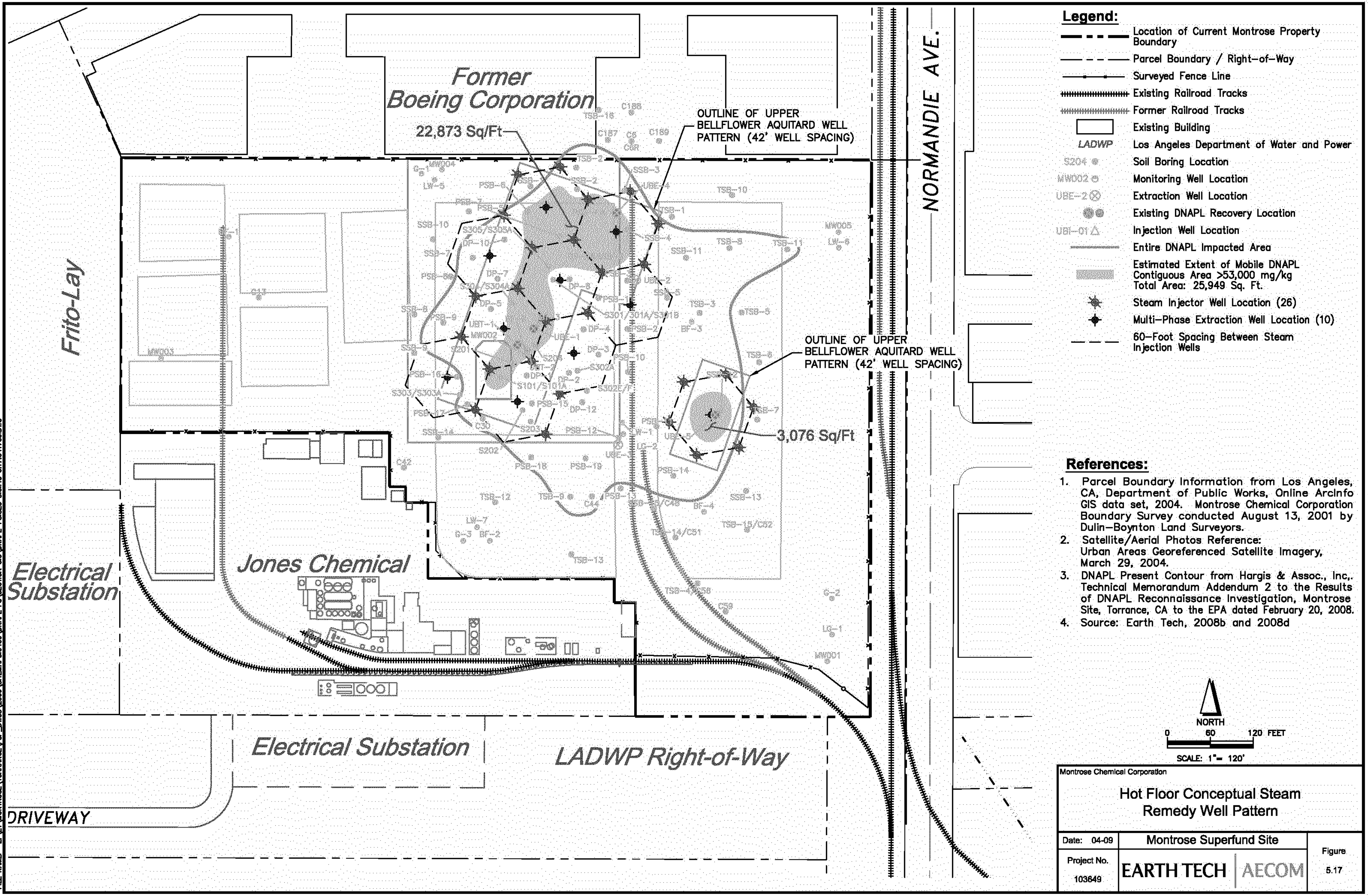
Montrose Chemical Corporation

Focused Treatment Area
Conceptual Steam Remedy
Process Flow Diagram

Date: 04-09	Montrose Superfund Site	Figure 5.16
Project No. 103649	EARTH TECH AECOM	

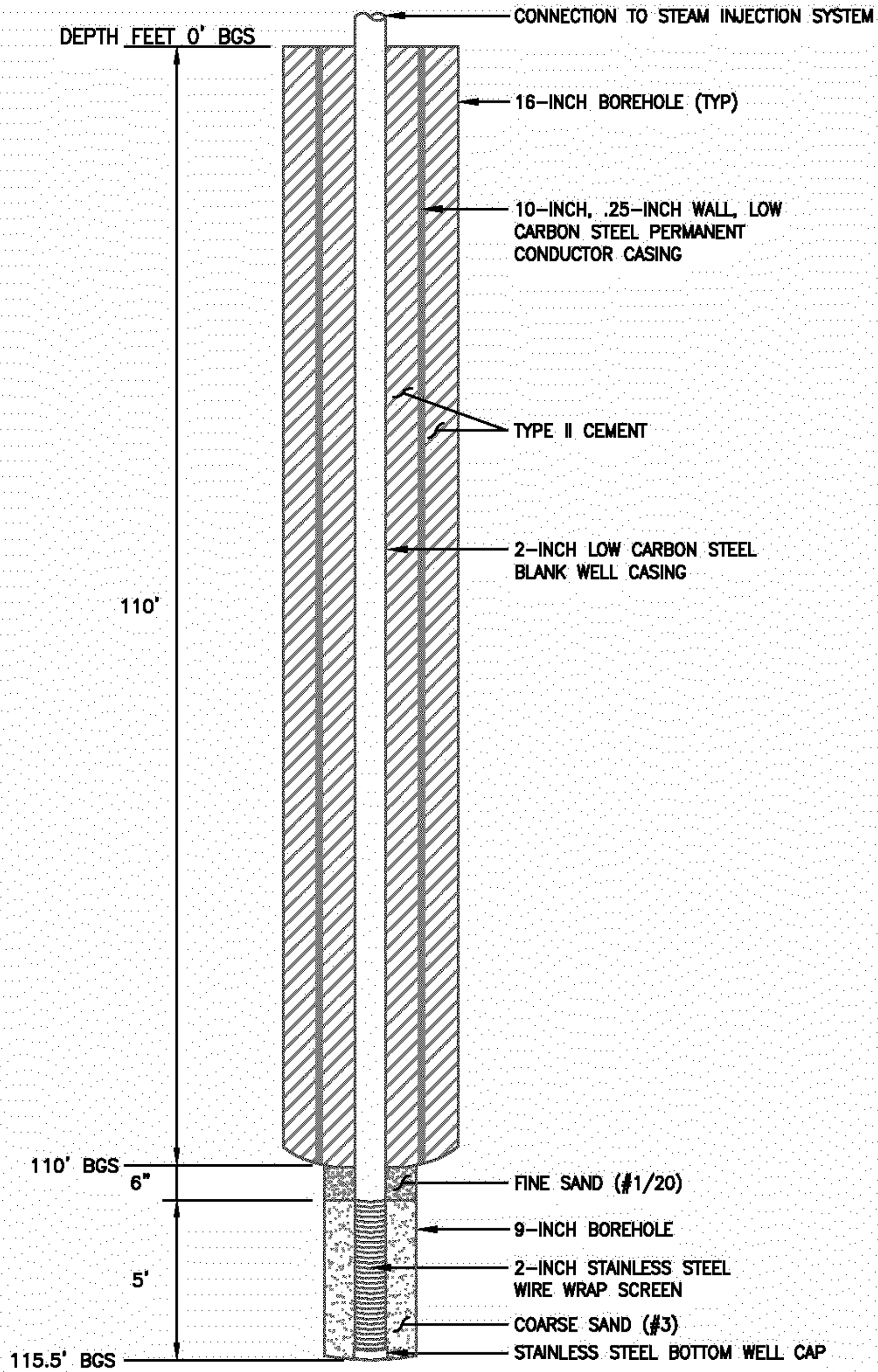
FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.16.041709.DWG

BOE-C6-0059895



FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.17.041709.DWG

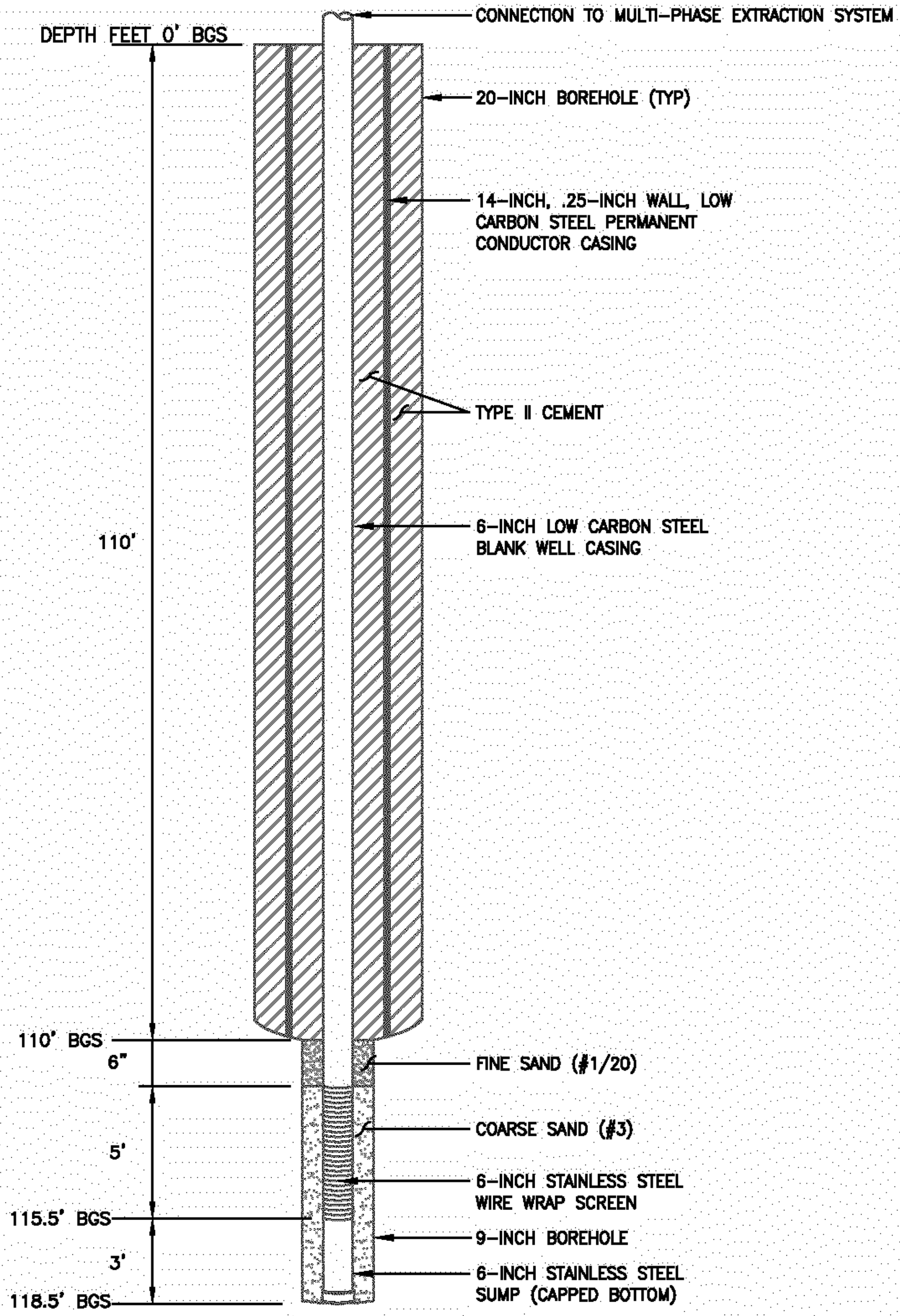
BOE-C6-0059896



TYPICAL WELL CONSTRUCTION DIAGRAM – NOT TO SCALE

Montrose Chemical Corporation	Hot Floor Steam Injection Well Construction Diagram	
Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	5.18

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\DNAPL-FS.SEC 5.0\SECTION 5.0.FIG 5.18.041709.DWG



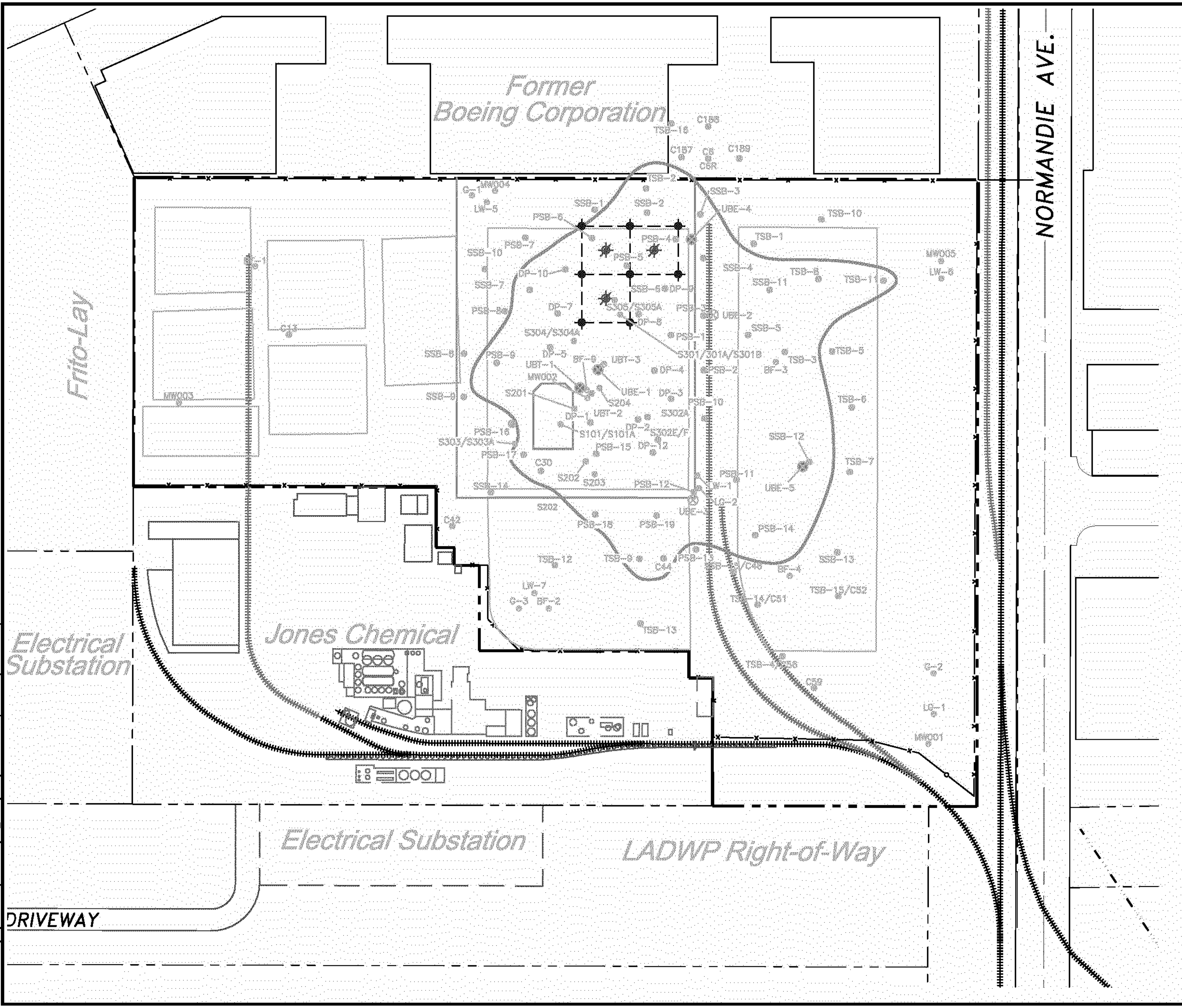
TYPICAL WELL CONSTRUCTION DIAGRAM – NOT TO SCALE

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.19.041709.DWG

Montrose Chemical Corporation

Hot Floor Multi-phase Extraction Well Construction Diagram

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	5.19



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP Los Angeles Department of Water and Power
- S204 Soil Boring Location
- MW002 Monitoring Well Location
- UBE-2 Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 Injection Well Location
- Entire DNAPL Impacted Area
- Steam Injector Well Location (3)
- Multi-Phase Extraction Well Location (8)
- 60-Foot Spacing Between Steam Injection Wells

References:

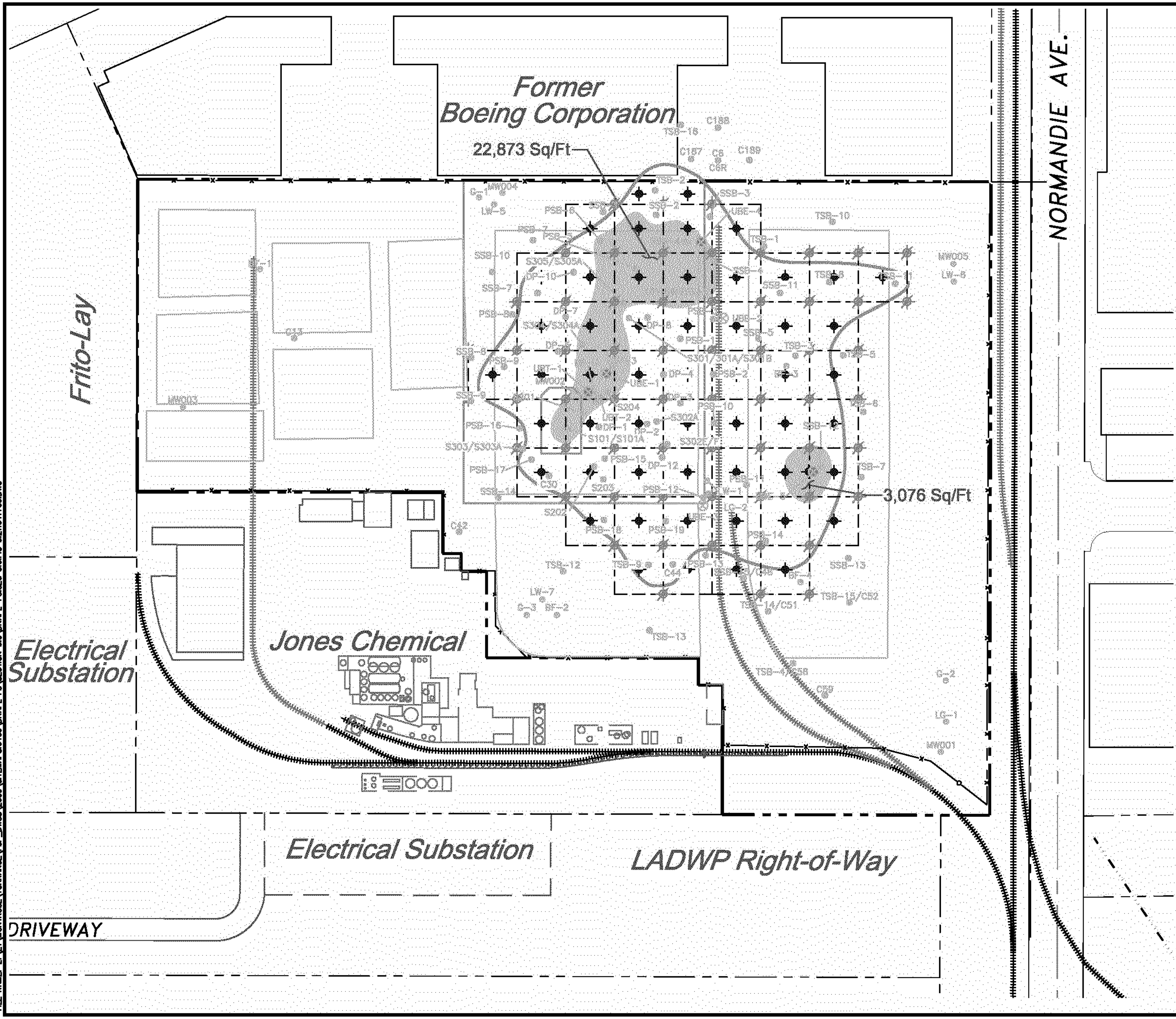
1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2008b and 2008c

Montrose Chemical Corporation

Upper Bellflower Aquitard Conceptual Steam Remedy Pilot Test Well Pattern

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	5.20

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS-SEC 5.0.FIG 5.20.041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- Entire DNAPL Impacted Area
- Estimated Extent of Mobile DNAPL Contiguous Area >53,000 mg/kg Total Area: 25,949 Sq. Ft.
- Steam Injector Well Location (61)
- Multi-Phase Extraction Well Location (53)
- 60-Foot Spacing Between Steam Injection Wells (42-Foot Spacing Between Steam Injection and Extraction Wells)

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc., Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2008b and 2008d

NORTH

0 60 120 FEET

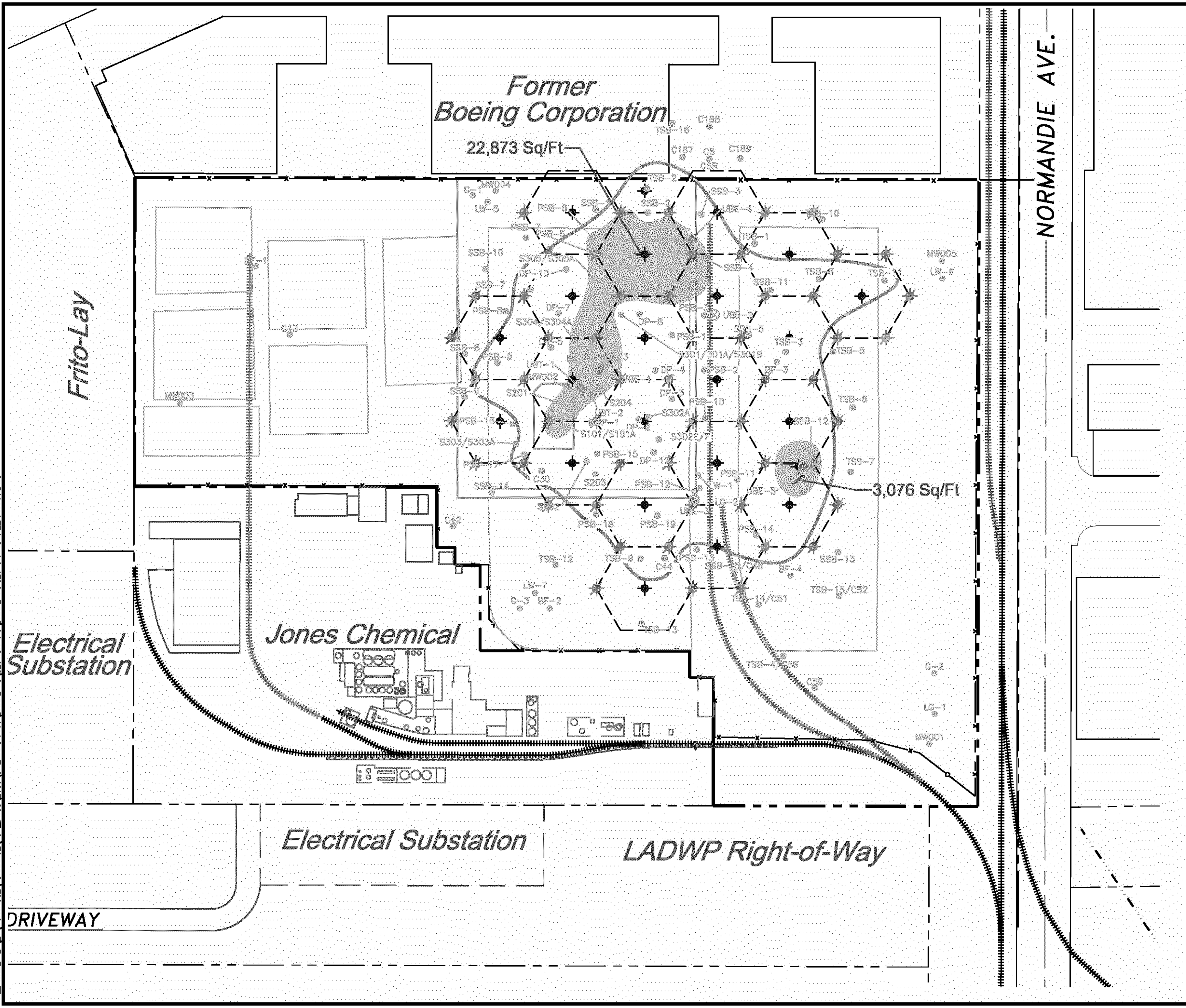
SCALE: 1"= 120'

Montrose Chemical Corporation

UBA Conceptual Steam Remedy Well Pattern - 42-Foot Spacing Entire DNAPL Impacted Area

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	5.21

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.21.041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- Entire DNAPL Impacted Area
- Estimated Extent of Mobile DNAPL Contiguous Area >53,000 mg/kg Total Area: 25,949 Sq. Ft.
- Steam Injector Well Location
- Multi-Phase Extraction Well Location
- 60-Foot Spacing Between Steam Injection Wells

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2008b and 2008d

NORTH

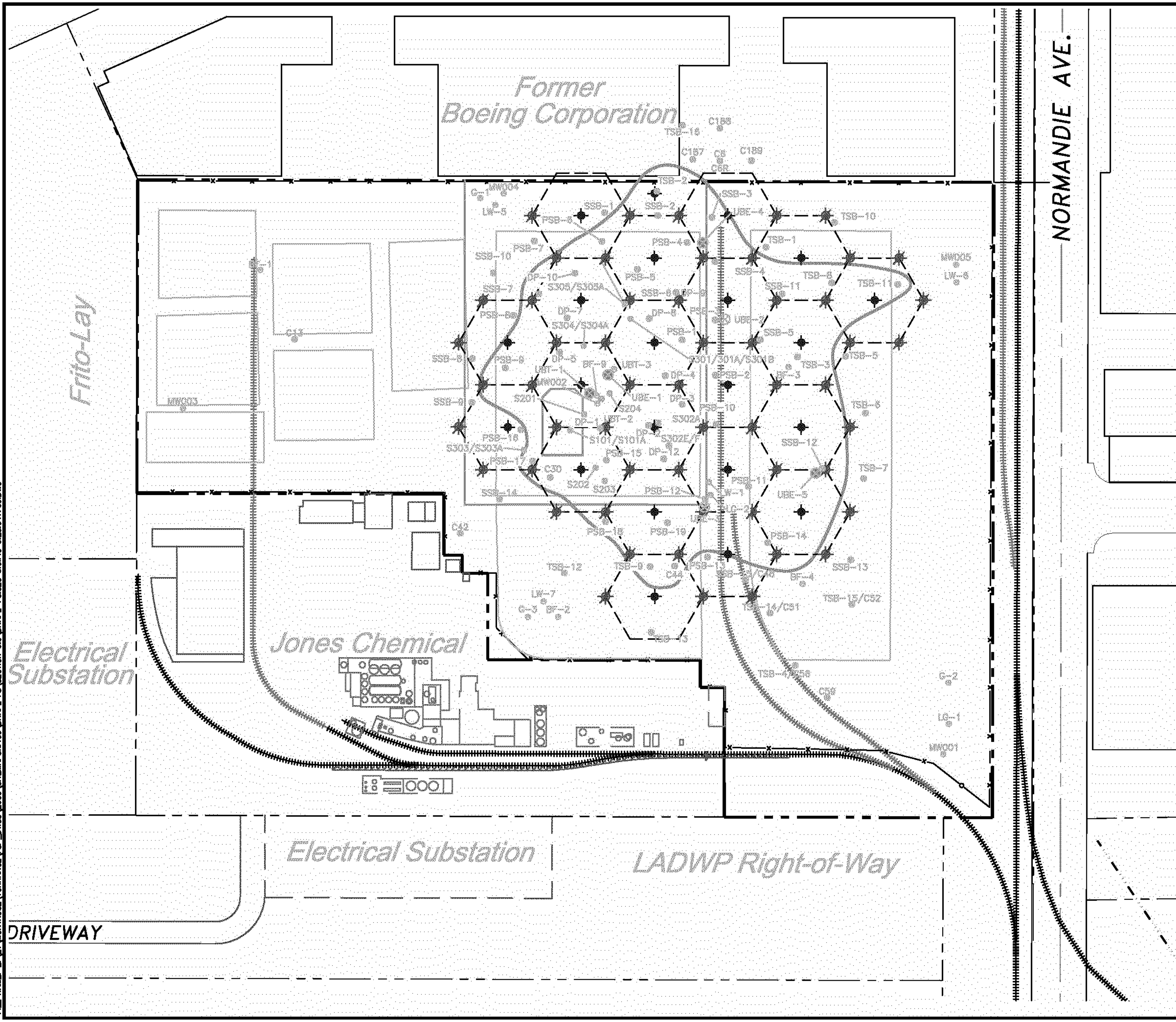
0 60 120 FEET

SCALE: 1"= 120'

Montrose Chemical Corporation

UBA Conceptual Steam Remedy
Well Pattern - 60-Foot Spacing
Entire DNAPL Impacted Area

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	5.22



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- Entire DNAPL Impacted Area
- Steam Injector Well Location (55)
- Multi-Phase Extraction Well Location (22)
- 60-Foot Spacing Between Steam Injection Wells

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2008b and 2008c

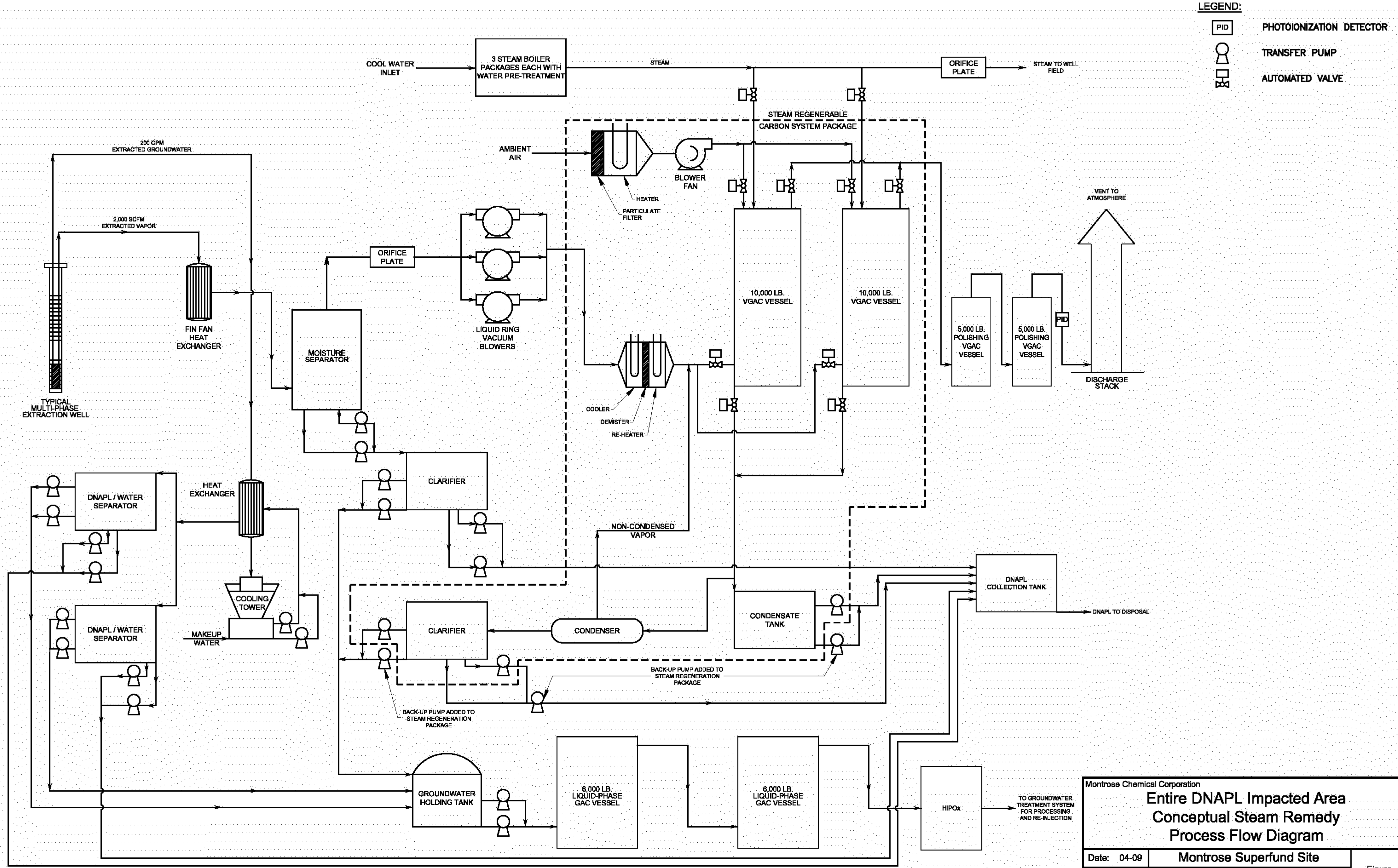
Montrose Chemical Corporation

Hot Floor Conceptual Steam Remedy Well Pattern

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	5.23

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.23.041709.DWG

BOE-C6-0059902



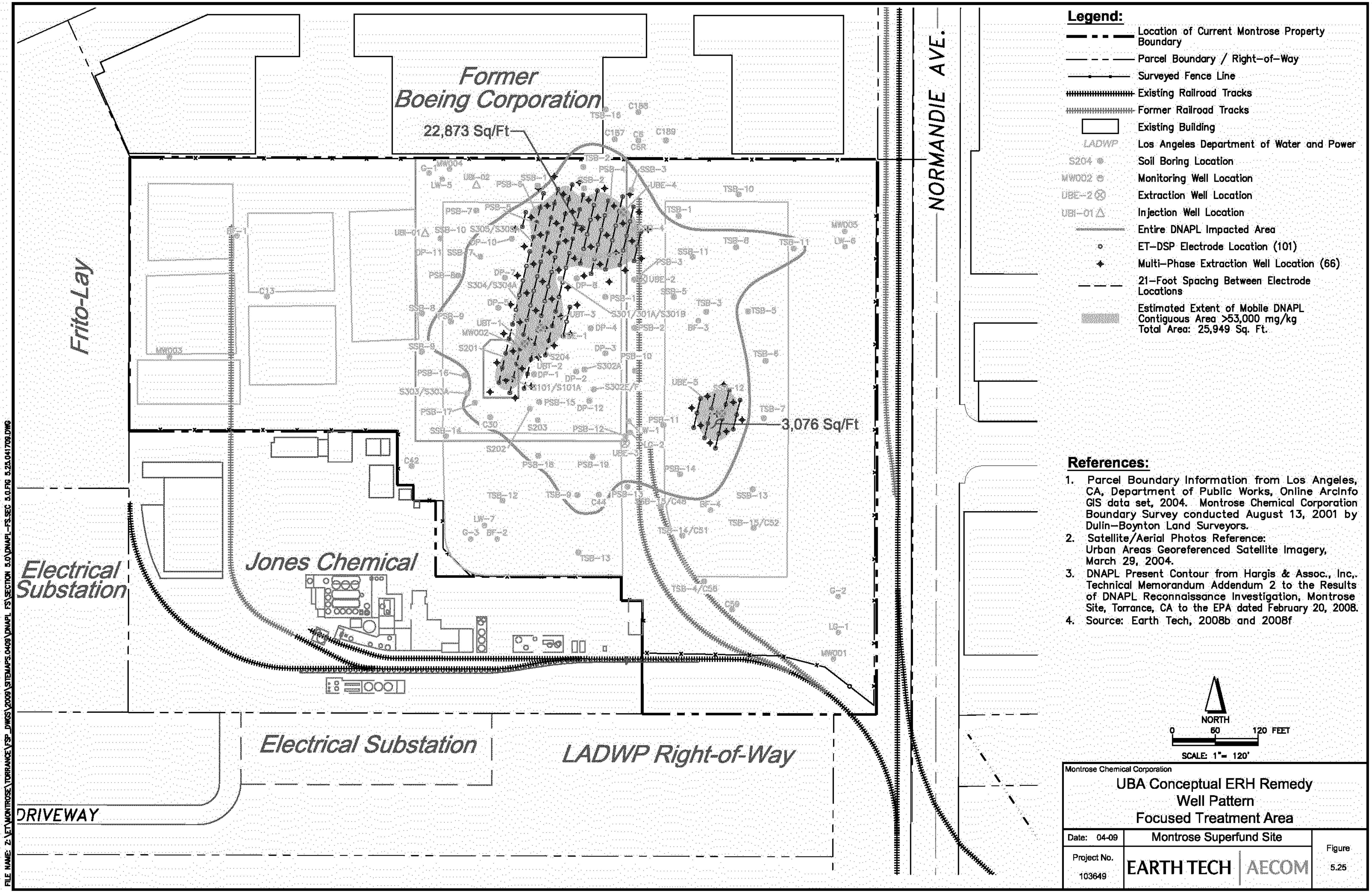
Montrose Chemical Corporation

Entire DNAPL Impacted Area Conceptual Steam Remedy Process Flow Diagram

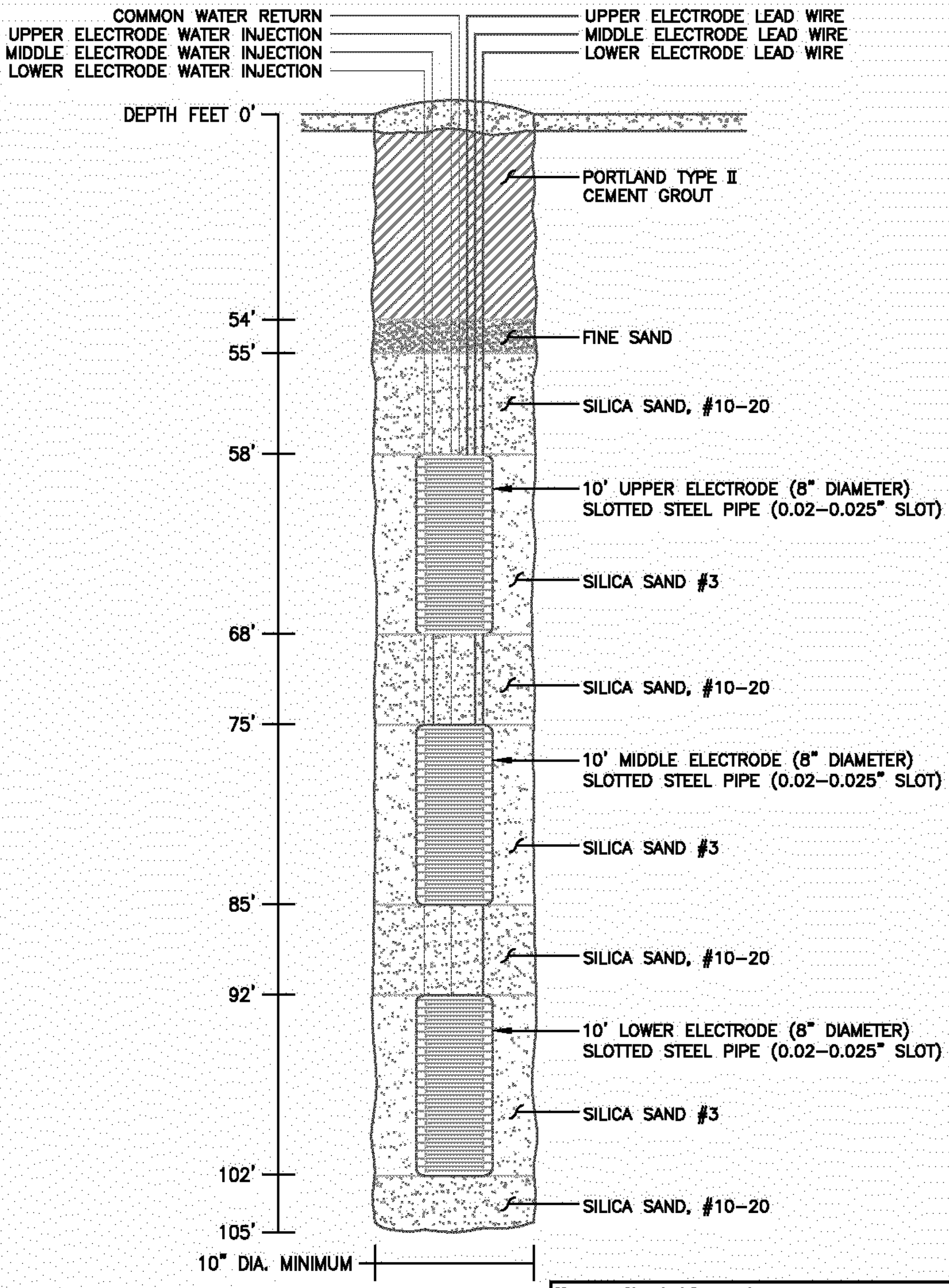
Date: 04-09	Montrose Superfund Site	Figure 5.24
Project No. 103649	EARTH TECH AECOM	

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.24.041709.DWG

BOE-C6-0059903



BOE-C6-0059904



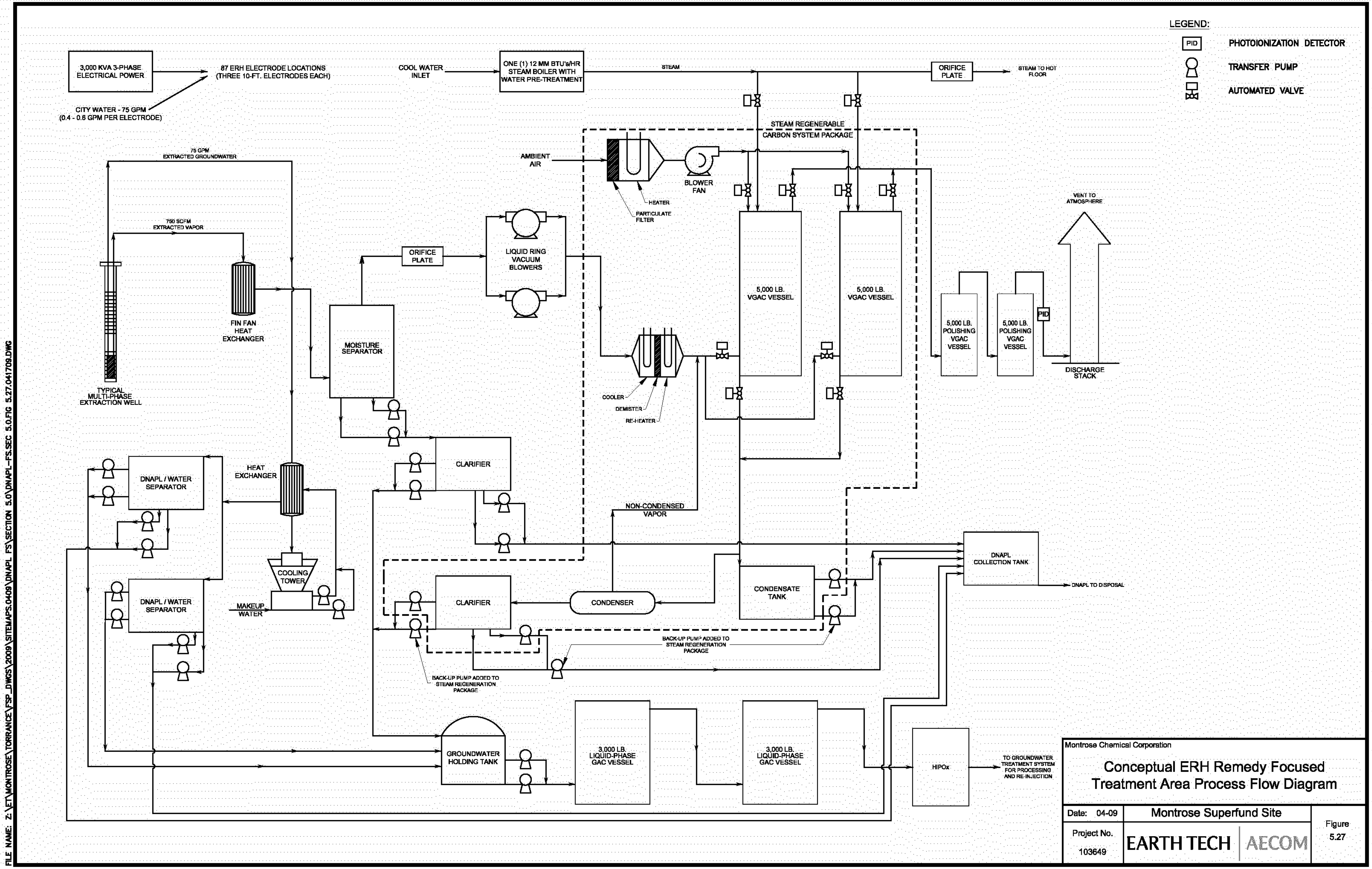
TYPICAL WELL CONSTRUCTION DIAGRAM – NOT TO SCALE

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.26.041709.DWG

Montrose Chemical Corporation

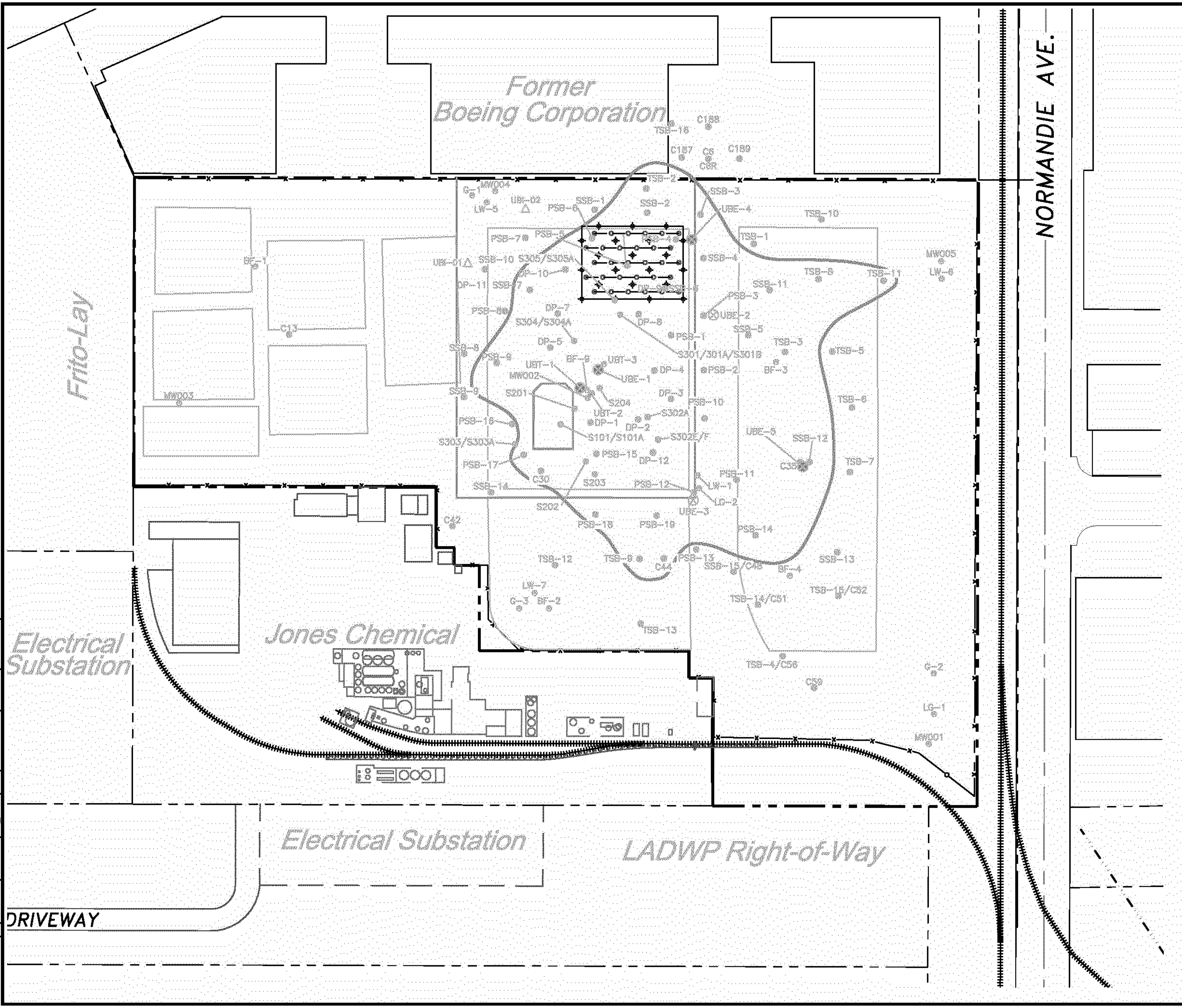
UBA ERH Electrode Well
Construction Diagram

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	5.26



FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL_FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.27.041709.DWG

BOE-C6-0059906



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP — Los Angeles Department of Water and Power
- S204 — Soil Boring Location
- MW002 — Monitoring Well Location
- UBE-2 — Extraction Well Location
- Existing DNAPL Recovery Location
- UBI-01 — Injection Well Location
- Entire DNAPL Impacted Area
- ET-DSP Electrode Location (30)
- Multi-Phase Extraction Well Location (21)
- 21-Foot Spacing Between Electrode Locations

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2008b and 2008e

NORTH

0 60 120 FEET

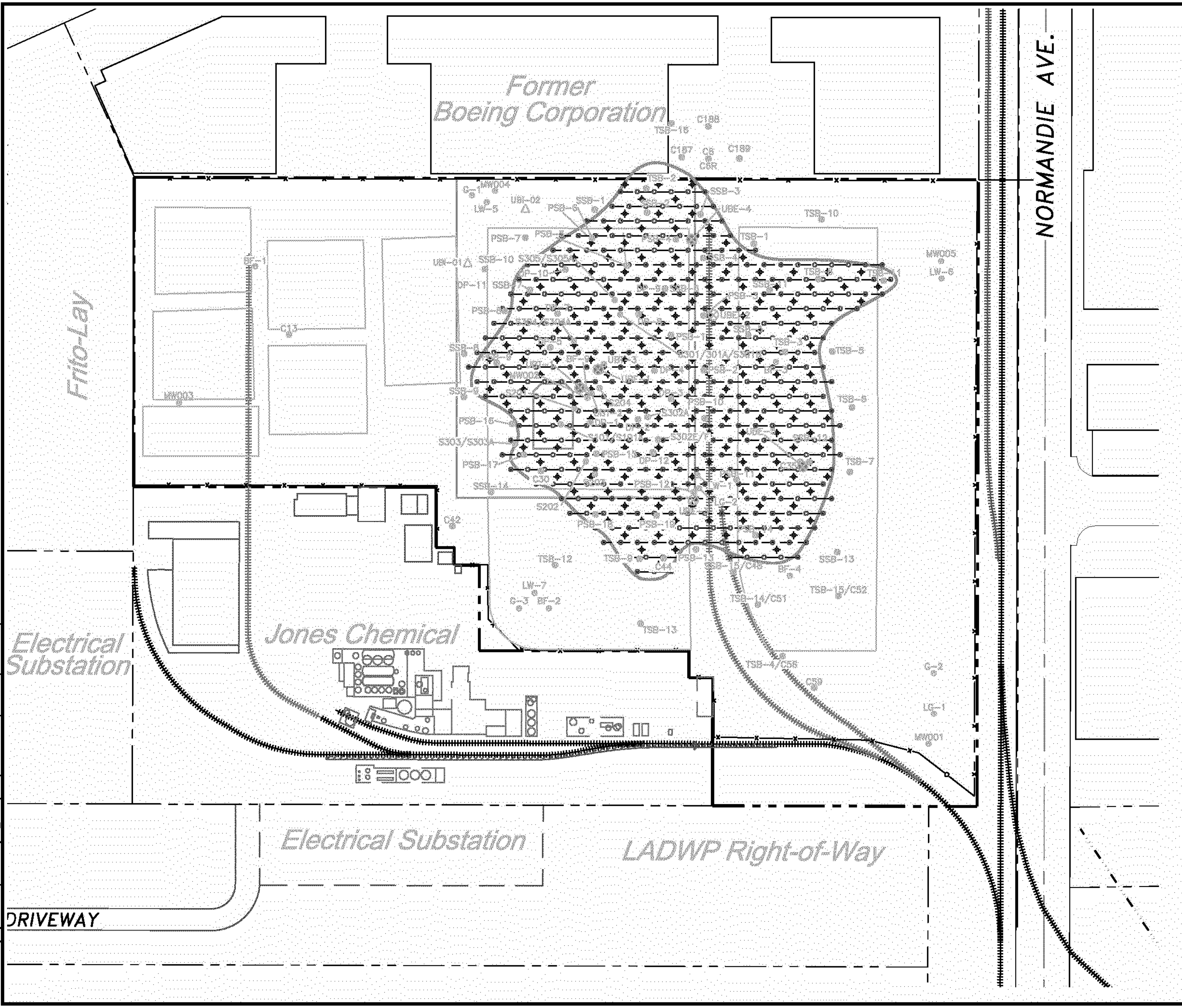
SCALE: 1"= 120'

Montrose Chemical Corporation

Upper Bellflower Aquitard Conceptual ERH Remedy Pilot Test Well Pattern

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH AECOM	5.28

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.28.041709.DWG



Legend:

- Location of Current Montrose Property Boundary
- Parcel Boundary / Right-of-Way
- Surveyed Fence Line
- Existing Railroad Tracks
- Former Railroad Tracks
- Existing Building
- LADWP Los Angeles Department of Water and Power
- S204 Soil Boring Location
- MW002 Monitoring Well Location
- UBE-2 Extraction Well Location
- UBI-01 Injection Well Location
- Entire DNAPL Impacted Area
- ET-DSP Electrode Location (456)
- Multi-Phase Extraction Well Location (203)
- 21-Foot Spacing Between Electrode Locations

References:

1. Parcel Boundary Information from Los Angeles, CA, Department of Public Works, Online ArcInfo GIS data set, 2004. Montrose Chemical Corporation Boundary Survey conducted August 13, 2001 by Dulin-Boynton Land Surveyors.
2. Satellite/Aerial Photos Reference: Urban Areas Georeferenced Satellite Imagery, March 29, 2004.
3. DNAPL Present Contour from Hargis & Assoc., Inc,. Technical Memorandum Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, CA to the EPA dated February 20, 2008.
4. Source: Earth Tech, 2008b and 2008e

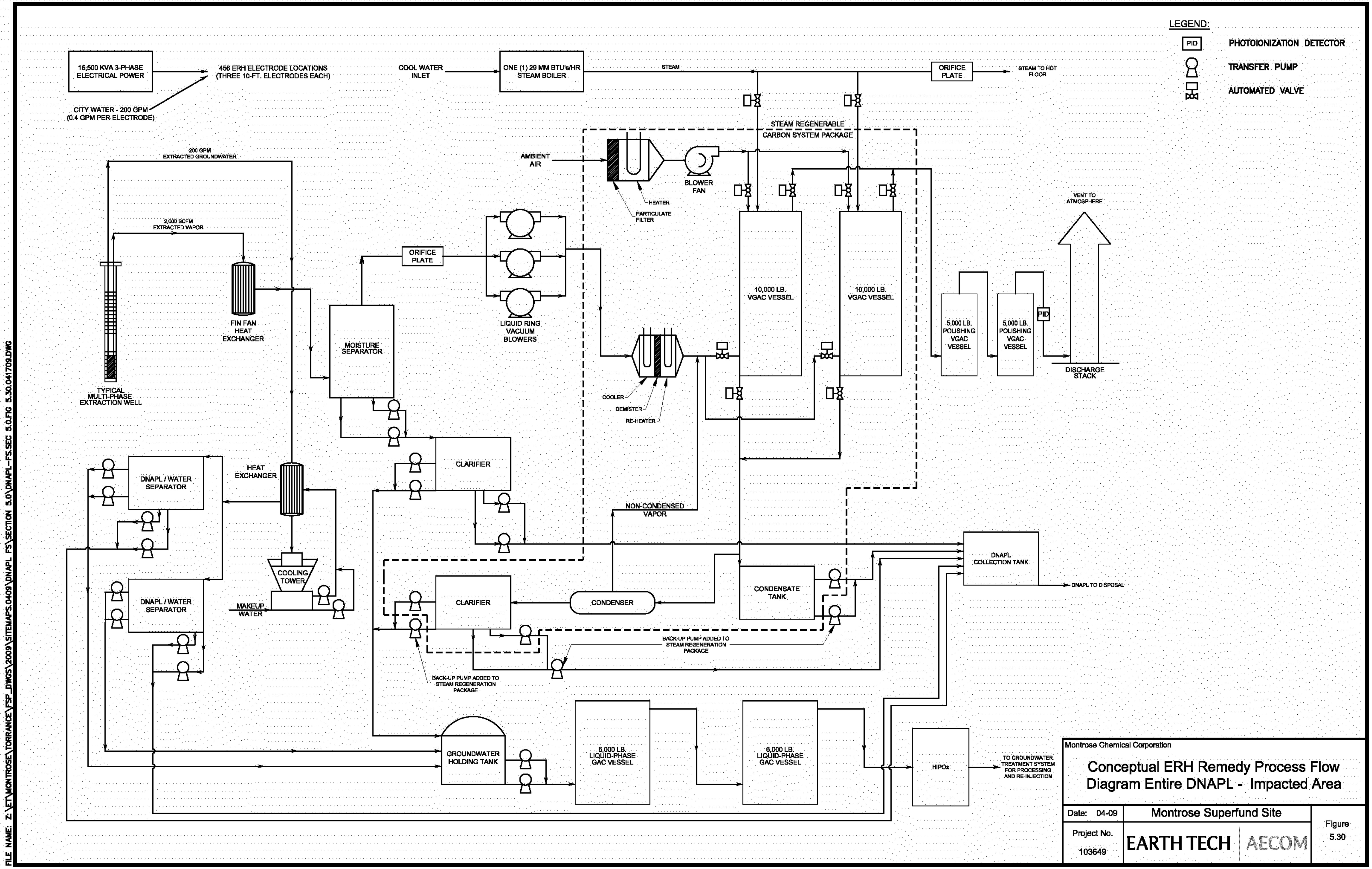
Montrose Chemical Corporation

UBA Conceptual ERH Remedy Well Pattern
Entire DNAPL - Impacted Area

Date: 04-09	Montrose Superfund Site	Figure
Project No. 103649	EARTH TECH | AECOM	5.29

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.29.041709.DWG

BOE-C6-0059908



Montrose Chemical Corporation

Conceptual ERH Remedy Process Flow Diagram Entire DNAPL - Impacted Area

Date: 04-09	Montrose Superfund Site		Figure 5.30
Project No. 103649	EARTH TECH	AECOM	

FILE NAME: Z:\ET\MONTROSE\TORRANCE\FSP_DWGS\2009\SITEMAPS.0409\DNAPL FS\SECTION 5.0\DNAPL-FS.SEC 5.0.FIG 5.30.041709.DWG

BOE-C6-0059909

Section 6.0

Detailed Analysis of Alternatives

6.0 DETAILED ANALYSIS OF ALTERNATIVES

This section presents the detailed analysis of the six RAs retained following the intermediate screening in Section 5.0. The six RAs are evaluated according to nine performance criteria defined by the NCP (40 CFR 300.430 (e)(9)). Section 6.1 briefly identifies and presents an overview of the nine performance criteria. The detailed evaluation of the six RAs is provided in Section 6.2. The performance of the six RAs relative to the nine criteria is then compared in Section 7.0. The RAs to be evaluated in this section are summarized as follows:

Candidate DNAPL Remedial Alternatives

Remedial Alternative	**GRA Remedial Technologies/Process Options**
Remedial Alternative 1	No Action Containment (required by Groundwater ROD)
Remedial Alternative 2	Containment (required by Groundwater ROD) Institutional Controls
Remedial Alternative 3	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone)
Remedial Alternative 4	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) Hydraulic Displacement, with untreated water injection
Remedial Alternative 5a	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) Steam Injection, focused treatment area, with hot floor
Remedial Alternative 6a	Containment (required by Groundwater ROD) Institutional Controls SVE (unsaturated zone) ERH, focused treatment area, without hot floor

6.1 DESCRIPTION OF EVALUATION CRITERIA

The NCP categorizes the nine evaluation criteria into three groups: threshold criteria, primary balancing criteria, and modifying criteria. Two of the nine criteria are designated as threshold criteria. The threshold criteria relate directly to statutory findings that must ultimately be met for remedy selection in the ROD. The two threshold criteria are:

- Overall protection of human health and the environment
- Compliance with ARARs

Five of the nine criteria are designated as balancing criteria. These are the primary performance criteria for the detailed analysis considering technical, cost, institutional, and risk concerns:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume throughout treatment
- Short-term effectiveness
- Implementability
- Cost

The final two criteria are designated as modifying criteria, which are used in the final analysis of remedial alternatives to modify an otherwise acceptable alternative, rather than choose among specific different alternatives:

- State acceptance
- Public acceptance

Modifying criteria are considered after public comments have been received on the draft FS documents and the proposed remedial plan. Those comments would be summarized in a Responsiveness Summary that is issued with the ROD. The following paragraphs briefly describe each of the evaluation criteria to be employed in this section.

6.1.1 THRESHOLD CRITERIA

The threshold criteria are described as follows:

Overall Protection of Human Health and the Environment. CERCLA requires that human health and the environment are protected by the selected remedy. RAs are evaluated for their ability to protect human health and the environment both in the short and long-term. Protectiveness can be achieved either through treatment, engineering, or institutional controls.

Compliance with ARARs. CERCLA requires that remedial actions comply with ARARs, as identified in Section 3.0. RAs are evaluated for their ability to comply with ARARs during remedy implementation, or alternately, if a waiver of ARARs is applicable.

6.1.2 Balancing Criteria

The balancing criteria are described as follows:

Long-Term Effectiveness and Permanence. Long-term effectiveness refers to the period after the remedial action is complete. RAs are evaluated for their ability to meet DNAPL RAOs and protect human health and the environment in the long-term. The permanence and reliability of the RAs are evaluated relative to the risks posed by residual contaminants left at the Site.

Reduction in Toxicity, Mobility, or Volume Through Treatment. RAs are evaluated for their ability to reduce the toxicity, mobility, or volume of hazardous substances at the Site. This criterion focuses on the quantity of hazardous substances removed, destroyed, or treated, the irreversibility of the treatment process, and the type, quantity, and mobility of residuals left in place following remedial action.

Short-Term Effectiveness. Short-term effectiveness refers to the period during remedy implementation. RAs are evaluated for their ability to protect human health and the environment in the short-term. The short-term is defined by the remedy duration and is based on the time required for RAOs to be met. The remedy duration will vary for each RA. If treatment at the Site is part of the RA, this evaluation will assess how well the ex-situ treatment system meets the cleanup goals or discharge criteria (i.e., for air or water). The short-term effectiveness evaluation focuses on protection to Site workers and the community during remedy construction and implementation.

Implementability. Alternatives are evaluated relative to the technical and administrative feasibility of implementing the RA, as well as the availability of necessary goods and services. The technical feasibility refers to the ability to construct and reliably operate and maintain the components of the RAs. The administrative feasibility refers to the ability to obtain approvals from regulatory agencies and the availability of vendors, specific equipment, technical specialists, or waste disposal services.

Cost. The cost of each RA is estimated in accordance with EPA guidance document *Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (EPA, 2000). In accordance with this guidance document, order-of-magnitude cost estimates (+50/-30 percent) were prepared based on a conceptual design for each RA as presented in Section 5.1. However, significant efforts have been made to estimate costs for many of the candidate RAs, and the relative accuracy of the cost estimates is believed to be narrower than the typical range required for feasibility studies as indicated above. Where applicable, RA costs include remedial design, construction, operation and maintenance, remedy verification, and abandonment. Costs are based on subcontractor/vendor quotations, catalogue or list prices, California Means prices, cost reconciliation discussions, and engineering experience.

The present-worth of each RA was estimated in accordance with the 2000 EPA guidance document and for purposes of comparing RAs with different remedy durations. The present-worth of a project is the amount of money that, if invested at the start of the remedial action, would be sufficient to fund all the costs associated with that RA over its planned duration. For this DNAPL FS, the present-worth costs (or net present value (NPV)) have been estimated assuming a discount rate of 4%. This discount rate reflects the difference between an assumed 7% investment rate of return and an inflation rate of 3%. The average US inflation rate in 2007 was 2.85%, which was the basis for assuming a 3% inflation rate. Furthermore, the 2000 EPA guidance document references the Office of Management and Budget Circular A-94. That circular was last updated January 2008, and the real discount rate indicated for a 7-year period is 2.4% (adjusted down for inflation). The nominal discount rate is 4.4%, without the inflation adjustment. Therefore, the 4% discount rate assumed for this FS is reasonable and consistent with current inflation rates and financial indicators. Annual RA costs are discounted to present-worth dollars (i.e., at Time 0), meaning that Year 1 costs are discounted one year. Year 2 costs are discounted two years, and so on.

6.1.3 MODIFYING CRITERIA

The modifying criteria are discussed as follows:

State Acceptance. This criterion considers the concerns that the State, both technical and administrative, regarding the candidate RAs and DNAPL FS. State concerns and acceptance issues will be presented in the ROD once the State has commented on the DNAPL FS and Proposed Plan. As such, State acceptance cannot be discussed in this draft FS and is deferred to the ROD.

Public Acceptance. This criterion considers the concerns that the public may have regarding the candidate RAs and DNAPL FS. Following preparation of the DNAPL FS and Proposed Plan, the public will be invited to comment on the DNAPL FS and candidate RAs. Public comments will be addressed by EPA in the ROD. Although public acceptance cannot be determined in advance of the public comment period, Montrose is aware of public concerns expressed during prior comment periods and at other Southern California Superfund Sites. Therefore, where the public is expected to express concern regarding a particular RA component (based on past experience), the concern is identified in this FS. Actual public concerns will be presented in the ROD once the public has commented on the DNAPL FS and the Proposed Plan.

6.2 ANALYSIS OF REMEDIAL ALTERNATIVES

The detailed analysis of each candidate RA is presented in this section, including RAs 1, 2, 3, 4, 5a, and 6a. The performance of each RA relative to the nine NCP criteria is discussed in each subsection below in sequential order, from RA 1 through RA 6a. A summary of the RA performance analysis is provided in **Table 6.1**, and detailed cost estimates for each of the candidate RAs is provided in **Appendix J**. The performance of the RAs will be compared against one another in Section 7.0, and therefore, is not discussed in this section (with a few exceptions).

6.2.1 REMEDIAL ALTERNATIVE 1 – NO ACTION

This RA includes two GRAs: (1) No Action for DNAPL in both the unsaturated and saturated zones, and (2) containment in the saturated zone as required by the Groundwater ROD.

Overall Protection of Human Health and the Environment. The remedies for soil and groundwater are expected to limit contaminant exposure pathways, thereby protecting human health. Exposure to contaminants at surface will be addressed by the remedy for soil, and exposure to dissolved-phase contaminants are addressed by the remedy for groundwater. The extent of DNAPL is fully within the TI Waiver Zone, and there is no risk of DNAPL migration outside the TI Waiver Zone. Migration of contaminants in the dissolved-phase is controlled by the hydraulic containment component of this RA, and DNAPL mass is reduced over time by dissolution. However, as with all of the RAs being considered, VOCs and DNAPL in the unsaturated zone would be left in place and serve as a source of contaminants to groundwater. ***Rank: Moderately Protective.***

Compliance with ARARs. Although the remedies for soil and groundwater will include institutional controls, this No Action RA may not be in compliance with Land Use Covenant requirements under CCR Title 22 and the California Civil Code. Deed restrictions may be required to prevent exposure to DNAPL-impacted soils in the long-term, depending on the provisions established for soil and groundwater. The remedy for groundwater ensures compliance with groundwater-related ARARs, and the DNAPL occurs fully within the TI Waiver Zone. ***Rank: Does Not Comply.***

Long-Term Effectiveness and Permanence. Through dissolution and the hydraulic containment component of this RA, DNAPL mass is reduced over time. After an estimated 4,900 years (as described in Section 5.1.1), the mass of DNAPL in the saturated UBA will have been reduced to a level that meets ARARs within the UBA. Any mass that is present in the BFS is also expected to be reduced to a level that meets ARARs within this timeframe. Reduction of DNAPL mass in the saturated zone provides a permanent solution. However, no treatment of VOC or DNAPL mass would occur within the unsaturated zone under this RA. ***Rank: Moderately Effective (in saturated zone only).***

Reduction of Toxicity, Mobility, and/or Volume of Hazardous Constituents. Although the toxicity, mobility, and volume of VOCs and DNAPL in the unsaturated zone are not reduced under this RA by active remediation, over time, the volume of DNAPL in the saturated zone is reduced by dissolution and hydraulic containment. Thus, the toxicity of the DNAPL-impacted soils is gradually reduced over time. Additionally, the Groundwater ROD recognizes that control of vertical hydraulic gradients is essential to reducing mobility of the DNAPL and is a required component of the remedy for groundwater. Lastly, the mobility of the DNAPL below the water table will be reduced gradually over time since dissolution is a depleting technology. ***Rank: Reduces Toxicity, Mobility, and Volume (in saturated zone only).***

Short-Term Effectiveness. There are no short-term remedial actions considered by this RA, and so this evaluation criterion is not applicable. The remedies for soil and groundwater are expected to protect human health and the environment in the short-term. ***Rank: Effective.***

Implementability. By definition, the No Action RA is highly implementable. ***Rank: Implementable.***

Cost. For the purposes of this FS, long-term hydraulic containment costs, occurring after the conclusion of the groundwater remedy (i.e., after Year 50), are assumed to be associated with the DNAPL remedy. These long-term containment costs have not previously been estimated and were not identified in the Joint Groundwater Feasibility Study (EPA, 1999). Therefore, the estimated cost of long-term hydraulic containment and RA 1 is $1.1 MM NPV as shown in Table 6.1 and Appendix J. Assuming that hydraulic containment is implemented as indicated in Section 5.1.1, groundwater would be extracted at an average flow rate of approximately 225 gpm from 7 wells. The groundwater would be treated ex-situ before being re-injected into two Gage Aquifer wells. This estimate includes an assumed constant yearly cost of $241,000 for hydraulic containment O&M and includes routine well rehabilitation and extraction pump/controls replacement. The above cost additionally assumes that all major containment equipment is replaced every 20 years. Under these assumptions and a discount rate of 4%, it is noted that costs incurred after approximately Year 350 do not contribute at all (not even $1) to the NPV total. ***Rank: Low Cost ($1.1 MM NPV).***

State Acceptance. This criterion will be discussed in more detail once comments on the Final DNAPL FS are received from the State. EPA will address this criterion in the ROD. However, it is noted that this RA would not emit any greenhouse gases or contribute to global warming, which may be favorable to the State. ***Rank: Not Applicable.***

Public Acceptance. RA 1 may be accepted by the public because it is protective of human health and reduces DNAPL mass in the long-term by hydraulic containment and dissolution. There are no ex-situ soil vapor or groundwater treatment systems and no ex-situ DNAPL accumulation tanks, eliminating the potential for release of contaminants to air, ground surface, or storm water. All VOCs and DNAPL would remain in the subsurface for containment via the remedies for soil and groundwater and gradual mass reduction in the long-term, which is consistent with the established TI Waiver Zone. This RA would not emit any greenhouse gases or contribute to global warming, which may be favorable to the public. ***Rank: May Be Accepted.***

6.2.2 REMEDIAL ALTERNATIVE 2 – INSTITUTIONAL CONTROLS

This RA includes two GRAs: (1) institutional controls, and (2) containment in the saturated zone as required by the Groundwater ROD.

Overall Protection of Human Health and the Environment. Similar to RA 1, the remedies for soil and groundwater are expected to limit contaminant exposure pathways thereby protecting human health. Exposure to contaminants at surface will be addressed by the remedy for soil, and exposure to dissolved-phase contaminants are addressed by the remedy for groundwater. The institutional controls component of this RA provides additional protectiveness by restricting Site access and uses that may result in exposure to DNAPL-impacted soils. The extent of DNAPL occurs fully within the TI Waiver Zone, and there is no risk of DNAPL migration outside the TI Waiver Zone. Additionally, nearly all of the DNAPL occurs at the Montrose Property where land use can be effectively controlled. The hydraulic containment component of this RA (required by the remedy for groundwater) protects the environment by controlling migration of contaminants in the dissolved-phase, and DNAPL mass is reduced over time by dissolution. However, as with all of the RAs being considered, VOCs and DNAPL in the unsaturated zone would be left in place and serve as a source of contaminants to groundwater. ***Rank: Protective.***

Compliance with ARARs. The institutional controls component of this RA would comply with Land Use Covenant requirements under CCR Title 22 and the California Civil Code. Compliance with this ARAR at the Montrose Property where nearly all of the DNAPL occurs should not be problematic. However, a small amount of DNAPL may occur at the former Boeing Realty Corporation property bordering the Property to the north. Compliance with land use ARARs at the off-Site property would require consent by the land owner and may be problematic. ***Rank: Complies.***

Long-Term Effectiveness and Permanence. The long-term effectiveness of this RA is the same as for RA 1. Long-term effectiveness is accomplished through dissolution and the hydraulic containment component of this RA. Any mass that is present in the BFS is also expected to be reduced to a level that meets ARARs within the containment timeframe. Reduction of DNAPL mass in the saturated zone provides a permanent solution. The institutional controls component of this RA does not increase the long-term effectiveness, and no treatment of VOC or DNAPL mass would occur within the unsaturated zone under this RA. ***Rank: Moderately Effective (in saturated zone only).***

Reduction of Toxicity, Mobility, and/or Volume of Hazardous Constituents. The performance of this RA relative to this criterion is the same as for RA 1. Although the toxicity, mobility, and volume of VOCs and DNAPL in the unsaturated zone are not reduced under this RA by active remediation, over time, the volume of DNAPL in the saturated zone is reduced by dissolution and hydraulic containment. Thus, the toxicity of the DNAPL-impacted soils is gradually reduced over time. The Groundwater ROD recognizes that control of vertical hydraulic gradients is essential to reducing mobility of the DNAPL and is a required component of the remedy for groundwater. The mobility of the DNAPL below the water table will be reduced gradually over time since dissolution is a depleting technology. The institutional controls component of this RA also does not reduce the toxicity, mobility, or volume of hazardous constituents at the Site. ***Rank: Reduces Toxicity, Mobility, and Volume (in saturated zone only).***

Short-Term Effectiveness. There are no short-term remedial actions considered by this RA, so this evaluation criterion is not applicable. The remedies for soil and groundwater are expected to protect human health and the environment in the short-term. The institutional controls component of this RA provides additional protectiveness by restricting Site access and uses that may result in exposure to DNAPL-impacted soils. ***Rank: Effective.***

Implementability. As described in Section 5.2.2, there are no technical or administrative aspects that would limit the implementability of recording a deed restriction for the on-Property portion of the Site, where nearly all of the DNAPL in the subsurface occurs. A small portion of the DNAPL may be present below the adjacent property to the north (former Boeing Realty Corporation), and application of deed restrictions at the off-Property areas would require consent of the land owners. ***Rank: Implementable.***

Cost. The estimated cost of RA 2 is $1.3 MM NPV as shown in Table 6.1 and Appendix J. This estimated cost reflects recording of a Land Use Covenant at the Montrose Property and annual site inspections by the State for purposes of verifying that the Site is being used in accordance with the land use restrictions. Although potential costs for establishing a deed restriction in off-Property areas, if necessary, are uncertain, an allowance of $15,000 per property is included in this estimate. In accordance with EPA guidance protocols, the cost of this institutional controls component is included for the first 30 years. The hydraulic containment component of this RA, as described for RA 1, is included in this estimate. ***Rank: Low Cost ($1.3 MM NPV).***

State Acceptance. This criterion will be discussed in more detail once comments on the Final DNAPL FS are received from the State. EPA will address this criterion in the ROD. However, it is noted that this RA would not emit any greenhouse gases or contribute to global warming, which may be favorable to the State. ***Rank: Not Applicable.***

Public Acceptance. RA 2 may be accepted by the public because it is protective of human health and reduces DNAPL mass in the long-term by hydraulic containment and dissolution. The institutional controls component of this RA would provide additional administrative controls by restricting site use and activities with the potential for exposure to DNAPL-impacted soils. There are no ex-situ soil vapor or groundwater treatment systems and no ex-situ DNAPL collection tanks, eliminating the potential for release of contaminants to air, ground surface, or stormwater. All VOCs and DNAPL would remain in the subsurface for containment via the remedies for soil and groundwater and gradual mass reduction in the long-term, which is consistent with the established TI Waiver Zone. There is additionally no threat of adverse impacts or DNAPL migrating to previously unaffected areas under this RA. This RA would not emit any greenhouse gases or contribute to global warming, which may be favorable to the public. ***Rank: May Be Accepted.***

6.2.3 Remedial Alternative 3 – SVE in the Unsaturated Zone

This RA includes three GRAs: (1) SVE in the unsaturated zone, (2) institutional controls, and (3) containment in the saturated zone as required by the Groundwater ROD.

Overall Protection of Human Health and the Environment. Similar to RAs 1 and 2, the remedies for soil and groundwater are expected to limit contaminant exposure pathways, thereby protecting human health. Exposure to contaminants at surface will be addressed by the remedy for soil, and exposure to dissolved-phase contaminants are addressed by the remedy for groundwater. The extent of DNAPL is fully within the TI Waiver Zone, and there is no risk of DNAPL migration outside the TI Waiver Zone. RA 3 protects the environment by removing the source of VOCs and DNAPL in the permeable unsaturated zone (PVS and unsaturated UBA) overlying groundwater. The mass of VOCs and DNAPL in the permeable unsaturated zone would be significantly reduced by SVE, thereby reducing the future risk to groundwater from contaminant leaching. However, for all RAs, it is noted that VOCs will be left in place within the low permeability PD soils (4 to 25 feet bgs), where SVE is significantly less effective. RA 3 additionally protects human health and the environment by controlling VOC migration in soil gas in the short-term. The institutional controls component of this RA provides additional protectiveness by restricting Site access and uses that may result in exposure to DNAPL-impacted soils. The hydraulic containment component of this RA (required by the remedy for groundwater) protects the environment by controlling migration of contaminants in the dissolved-phase, and DNAPL mass is reduced over time by dissolution. ***Rank: Protective.***

Compliance with ARARs. RA 3 would comply with DNAPL ARARs. The institutional controls component of this RA would comply with Land Use Covenant requirements under CCR Title 22 and the California Civil Code. The SVE component of this RA would need to comply with federal and state ARARs related to air quality including the Clean Air Act and SCAQMD regulations. Additionally, RA 3 would need to comply with SCAQMD regulations governing emissions of toxic chemicals and potentially particulate matter and products of incomplete combustion, depending on the vapor treatment technology selected for the RA. All three vapor treatment technologies considered by this FS are capable of meeting the air emission ARARs.

The system would be designed to automatically terminate SVE operations in advance of exceeding the air emission ARARs. This RA would generate solid waste including soil cuttings, decontamination water, PPE, and spent carbon, and would need to comply with regulations governing waste classification, management, and disposal including CFR Title 40 and CCR Title 22. This RA would also have to comply with local municipal codes related to SVE system construction.

As described in Section 5.1.3, the carbon footprint of RA 3 is estimated at 2.2 million pounds of greenhouse gases, which would require an estimated 14,200 trees to offset the carbon dioxide production (Table 5.1 and Appendix H). This RA has the smallest carbon footprint (other than the zero footprints of RAs 1 and 2) of all the RAs considered in this FS. The lower carbon footprint complies with EPA green remediation initiatives and would advance the goals of the California Global Warming Act of 2006. ***Rank: Complies.***

Long-Term Effectiveness and Permanence. The long-term effectiveness of this RA is similar to RAs 1 and 2. Long-term effectiveness is accomplished through dissolution and the hydraulic containment component of this RA. The containment timeframe estimates assume that none of the unsaturated zone MCB mass leaches to groundwater, and therefore, the estimated duration for hydraulic containment under this RA is the same as for the No Action RA. Any mass that is present in the BFS is also expected to be reduced to a level that meets ARARs during the containment timeframe. RA 3 will reduce the mass of VOCs and DNAPL in the permeable unsaturated zone to a level that significantly reduces the future risk to the underlying groundwater from contaminant leaching. However, SVE would be significantly less effective in the low permeability PD soils, and VOC mass will not be significantly reduced within this interval (4 to 25 feet bgs). The permanence of the remedy is improved by removal of VOC/DNAPL mass from the unsaturated zone, but the required duration of hydraulic containment in the long-term is not reduced by this RA. ***Rank: Effective (highly effective in unsaturated zone).***

Reduction of Toxicity, Mobility, and/or Volume of Hazardous Constituents. The volume (and mass) of hazardous constituents in the unsaturated zone is reduced by RA 3. An estimated 261,000 pounds of MCB exists within the permeable unsaturated zone and is available for removal by SVE. Assuming a 95% mass removal efficiency, approximately 248,000 pounds of MCB would be removed from the unsaturated zone by this RA. VOCs, including the volatile fraction of DNAPL (i.e., MCB), are extracted from the unsaturated zone by SVE. DNAPL mobility in the unsaturated zone is also reduced by volatilization of the MCB component since the DDT component of the DNAPL will sorb strongly to soil and is relatively immobile in the environment. The toxicity of the unsaturated soils and soil gas is also reduced by this RA.

The volume of DNAPL and toxicity of the VOC component in the saturated zone is reduced over time by dissolution and hydraulic containment. The Groundwater ROD recognizes that control of vertical hydraulic gradients is essential to reducing mobility of the DNAPL and is a required component of the remedy for groundwater. The mobility of the DNAPL below the water table will be reduced gradually over time since dissolution is a depleting technology. This RA reduces the toxicity, mobility, and volume of hazardous constituents in both the unsaturated zone and below the water table. ***Rank: Reduces Toxicity, Mobility, and Volume.***

Short-Term Effectiveness. RA 3 is effective in protecting human health and the environment in the short-term. Under this RA, soil vapors are extracted from the permeable unsaturated zone for ex-situ treatment. All three candidate ex-situ vapor treatment technologies would be effective in treating Site contaminants and complying with air quality ARARs. Disposable carbon/resin is identified as the lowest cost treatment technology for this RA and was highly effective in meeting air emission standards during SVE field pilot testing in 2003. Vapor-phase Site contaminants (most notably MCB) are effectively treated by carbon/resin adsorption, and a relatively high MCB mass adsorption efficiency of 25% by weight was observed during field pilot testing. Additionally, this vapor treatment technology does not involve any combustion processes (such as thermal oxidation), steam-regeneration processes (such as with on-site carbon/resin regeneration), or any on-Site accumulation of condensed VOCs/DNAPL (such as with steam-regenerable carbon/resin). Spent carbon/resin is evacuated for off-Site recycling or disposal, and virgin carbon/resin is placed into the adsorber beds. Safe-work procedures would be employed during replacement of the carbon/resin to protect the health of on-Site workers and prevent release of any VOCs, nuisance odors, or carbon dust. Disposable carbon/resin is the least complex vapor treatment technology and is a reliable method for protecting human health and the environment during remedy implementation.

Engineering controls would be used to automatically terminate SVE operations if air emissions exceed limits, to ensure compliance with air quality standards at all times. A small volume of moisture condensate would also be generated by this SVE RA and, if the full scale groundwater remediation system is not on-line, temporarily accumulated on-Site in drums, and transported for off-Site disposal within 90 days of generation. The moisture separator and drum storage would be located within a secondary containment area to prevent accidental releases to the surface and stormwater pathways. Contaminated soil cuttings would be generated during SVE well installation and temporarily accumulated on-Site (in sealed roll-off bins) pending disposal. Safe-work procedures would be employed to protect the health of on-site workers during well installation activities and prevent release of any VOCs, nuisance odors, or dust. ***Rank: Effective.***

Implementability. As described in Section 5.2.3, there are no technical or administrative aspects that would limit the implementability of this RA. SVE is a widely used technology for remediating VOCs in permeable unsaturated soils, and equipment required to implement the RA is readily available. Highly skilled operators are not required for this RA, and there is a large number of contractors available to provide SVE remediation services. The SVE aspects of this RA would have to meet ARARs for air emissions. ***Rank: Implementable.***

Cost. The estimated cost of RA 3 is $5.9 MM NPV as shown in Table 6.1 and Appendix J. This cost includes $1.3 MM NPV for institutional controls and long-term hydraulic containment as estimated for RA 2. As described in Section 5.1.3, this cost assumes a total of 23 extraction wells and a 1,500 scfm vapor extraction and treatment system. Soil vapors are assumed to be treated using disposable carbon/resin, which was found to be the lowest cost treatment technology for the estimated MCB mass in the permeable unsaturated zone. If a steam-regenerable carbon system were used to treat soil vapors, the cost of this RA would increase to approximately $7 MM NPV. If a thermal oxidizer with acid gas scrubber were used to treat soil vapors, the cost of this RA would increase to nearly $8 MM NPV.

The duration of the remedy, which directly affects costs, is assumed to be 7 years total based on the following schedule of activities:

- Year 1 = Design
- Year 2 = Construction
- Years 3-6 = 4 years of O&M
- Year 7 = Verification and Abandonment

SVE operations are assumed to be approximately 4 years based on (i) an estimated 261,000 pounds of MCB in the permeable unsaturated zone; (ii) an initial MCB mass removal rate of 5,000 pounds per week; and (iii) a first order decay curve (Figure 5.4). Assuming a 25% MCB mass adsorption capacity, an estimated 20,000 pounds of disposable carbon would be consumed weekly at the start of the project. A 25% MCB mass adsorption efficiency was observed during SVE pilot testing and is consistent with carbon performance expectations based on published isotherms from carbon suppliers. ***Rank: Low to Moderate ($5.9 MM NPV).***

State Acceptance. This criterion will be discussed in more detail once comments on the Final DNAPL FS are received from the State. EPA will address this criterion in the ROD. ***Rank: Not Applicable.***

Public Acceptance. RA 3 may be accepted by the public because it is protective of human health and would reduce DNAPL mass in the long-term by hydraulic containment and dissolution. The protectiveness and permanence of this RA is further increased by SVE, which would reduce the mass of VOCs/DNAPL in the unsaturated zone. However, ex-situ vapor treatment would be required for this RA, and the public has expressed concern regarding the use of certain off-gas treatment technologies at other Superfund Sites. Most notably, the public has expressed concern regarding the potential for formation of dioxins and furans as products of incomplete combustion (PICs) during thermal oxidation of soil vapors. Indeed, public comments regarding this issue prompted EPA to select disposable carbon/resin (over thermal oxidation) as the vapor treatment technology for the Waste Pits Operable Unit at the Del Amo Superfund Site. There is no combustion process or potential for formation of PICs during vapor treatment using disposable carbon/resin. Disposable carbon/resin is expected to be the most acceptable vapor treatment technology to the public, while thermal oxidation is expected to be the least acceptable technology.

However, despite public concerns, it is noted that EPA selected thermal oxidation with acid gas scrubbing as the ex-situ soil vapor treatment technology at the Pemaco Superfund Site in Maywood, California. A high efficiency flameless thermal oxidizer was selected to minimize the potential for formation of PICs, and carbon was used to further treat the soil vapors prior to atmospheric discharge (but at an increased cost). The ex-situ soil vapor treatment system at the Pemaco Site was monitored for the presence of PICs during remedy implementation. Based on these precedents, all three of the ex-situ soil vapor treatment technologies should be considered as potentially applicable.

The institutional controls component of this RA would provide additional administrative controls by restricting site use and activities with the potential to impact DNAPL. There are no ex-situ groundwater treatment systems and no ex-situ DNAPL collection tanks associated with this RA, significantly reducing the potential for release of contaminants to ground surface or stormwater. All liquid-phase DNAPL would remain in the subsurface, where its mass would be reduced in the long-term by dissolution and hydraulic containment. The energy consumption, carbon footprint, and greenhouse gas emissions from this RA would be relatively low, which may be favorable to the public, and significantly lower than for RAs 5a and 6a. ***Rank: May Be Accepted (particularly if disposable carbon/resin is used).***

6.2.4 Remedial Alternative 4 – Hydraulic Displacement with Untreated Water Injection

This RA includes four GRAs: (1) hydraulic displacement with untreated water re-injection in the saturated UBA, (2) SVE in the unsaturated zone, (3) institutional controls, and (4) containment in the saturated zone as required by the Groundwater ROD.

Overall Protection of Human Health and the Environment. Similar to RAs 1 through 3, the remedies for soil and groundwater are expected to limit contaminant exposure pathways thereby protecting human health. Exposure to contaminants at surface will be addressed by the remedy for soil, and exposure to dissolved-phase contaminants are addressed by the remedy for groundwater. The extent of DNAPL is fully within the TI Waiver Zone. The institutional controls component of this RA provides additional protectiveness by restricting Site access and uses that may result in exposure to DNAPL-impacted soils.

RA 4 protects the environment by removing mobile DNAPL from the saturated UBA. Under RA 4, mobile DNAPL is removed by hydraulic displacement, reducing the risk of DNAPL migration either laterally within the UBA or downward into the BFS. Hydraulic displacement depletes the DNAPL saturation, thereby significantly reducing the mobility of the remaining DNAPL. The hydraulic containment component of RA 4 (required by the remedy for groundwater) protects the environment by controlling migration of contaminants in the dissolved-phase and reducing DNAPL mass in the long-term by dissolution. The SVE component of RA 4 additionally protects human health and the environment by removing the source of VOCs/DNAPL in the unsaturated zone (25 to 60 feet bgs) and controlling VOC migration in soil gas in the short-term.

Mobile DNAPL is hydraulically displaced during this remedy and effective recovery of the DNAPL is necessary to protect the environment from lateral spreading or downward migration. However, the risks associated with uncontrolled contaminant migration can be off-set to a significant extent by a higher well density, i.e. a closer well spacing. Candidate well spacings of only 25 and 50 feet are considered for this hydraulic displacement RA and are less than computer modeled distances, which predicted that hydraulic displacement would be effective even at well spacings of 120 feet. Additionally, computer modeling of hydraulic displacement predicted that no DNAPL would be mobilized past the basal silty sand member of the UBA or to the underlying BFS assuming DNAPL pool heights up to 8 feet (H+A, 2009b). Hydraulic displacement also depletes the DNAPL saturation, making the remaining DNAPL less and less mobile over time. ***Rank: Protective.***

Compliance with ARARs. RA 4 would comply with DNAPL ARARs. The institutional controls component of this RA would comply with Land Use Covenant requirements under CCR Title 22 and the California Civil Code. The SVE component of this RA would need to be constructed and operated to comply with federal and state ARARs related to air quality including the Clean Air Act and SCAQMD regulations. This RA would generate solid waste including soil cuttings, decontamination water, PPE, DNAPL, and spent carbon, and would need to comply with regulations governing waste classification, management, and disposal including CFR Title 40 and CCR Title 22. This RA would also have to comply with local municipal codes related to system construction. Hydraulic displacement wells installed under this RA would need to comply with California Well Standards. Separate-phase DNAPL is also temporarily accumulated on-Site (pending disposal) under this RA, and therefore, the aboveground tank would have to comply with regulations for hazardous material accumulation, including CFR Title 40 and CCR Title 22. Re-injection of untreated groundwater into the UBA at the Property would not comply with Groundwater ROD in-situ groundwater standards, which would need to be waived in the same manner as done for the 2004/2005 hydraulic displacement field pilot test.

As described in Section 5.1.4, the carbon footprint of RA 4 is estimated at 4.2 million pounds of greenhouse gases, requiring approximately 27,300 trees to offset the carbon dioxide production (Table 5.1 and Appendix H). This RA has one of the smaller carbon footprints of the RAs considered in this FS. The relatively low carbon footprint complies with EPA green remediation initiatives and advances the goals of the California Global Warming Act of 2006. ***Rank: Complies.***

Long-Term Effectiveness and Permanence. RA 4 is effective in the long-term. Long-term effectiveness is accomplished through dissolution and the hydraulic containment component of this RA. Any mass that is present in the BFS is also expected to be reduced to a level that meets ARARs within the containment timeframe. Under this RA, mobile DNAPL mass is removed from the saturated UBA by hydraulic displacement. The SVE component of this RA would reduce the VOC/DNAPL mass in the permeable unsaturated zone to a level that significantly reduces the future risk to the underlying groundwater from contaminant leaching. The permanence of the remedy is improved by removal of VOC/DNAPL mass from both the unsaturated and saturated zones. Ultimately, however, as with all of the DNAPL mass removal RAs under consideration, an insufficient amount of mass can be removed to meaningfully reduce the required duration of hydraulic containment in the long-term. ***Rank: Effective.***

Reduction of Toxicity, Mobility, and/or Volume of Hazardous Constituents. RA 4 reduces the volume of DNAPL in the saturated zone and significantly reduces the mobility of the DNAPL. An estimated 28% of the DNAPL mass at the Site is mobile DNAPL (221,800 pounds or approximately 21,000 gallons) and available for removal by hydraulic displacement. Mobile DNAPL is removed by the hydraulic displacement component of this RA, reducing the saturation of DNAPL remaining in the subsurface. The highest DNAPL saturations are the most mobile and are the easiest to recover by hydraulic displacement. DNAPL becomes significantly less mobile as the saturation is reduced. Hydraulic displacement is a depleting technology that works within the existing DNAPL architecture and continuously reduces the DNAPL mobility over time. If hydraulic displacement is effective in reducing DNAPL saturations to residual levels, then the DNAPL would be immobile and no longer a risk of further migration (other than as a source for dissolved-phase contaminants which are effectively addressed by hydraulic containment). High mass removal efficiencies approaching 100% of the mobile DNAPL are unlikely for RA 4, but 80% or 90% mass removal efficiencies of the mobile DNAPL are considered reasonable for RA 4, particularly if a high well density scenario is used for this RA. Assuming 80% mobile DNAPL mass reduction, an estimated 177,400 pounds of liquid-phase DNAPL (MCB+DDT) would be removed by RA 4. Hydraulic displacement under RA 4 would remove the most DNAPL-phase DDT from the subsurface of all RAs under consideration. Assuming that MCB represents 50% of the DNAPL mass, the estimated amount of MCB mass reduction under RA 4 would therefore be 88,700 pounds. In the long-term, the volume and toxicity of hazardous constituents in the saturated zone is reduced by dissolution and the hydraulic containment component of this RA.

Although DNAPL is mobilized by hydraulic displacement for recovery under RA 4, the mobility of the DNAPL to flow through porous media is not increased by this RA. RA 4 does not change the DNAPL physical properties. The density, viscosity, and interfacial tension of the DNAPL is the same before, during, and following hydraulic displacement. However, by reducing DNAPL saturations, RA 4 is effective in reducing the mobility of the DNAPL remaining in place at the end of the remedy. In this manner, the DNAPL mobility is reduced by RA 4, even though DNAPL is mobilized for recovery by hydraulic displacement during the remedy.

Field pilot testing has demonstrated the ability for hydraulic displacement to recover mobile DNAPL, reducing both the volume and mobility of hazardous constituents in the UBA. Up to 5.6 gallons per day per well of mobile DNAPL were recovered during field pilot testing at moderate hydraulic gradients, without the benefit of groundwater re-injection. Mobile DNAPL was recovered by hydraulic displacement from all wells located within the estimated mobile DNAPL footprint. Additionally, computer modeling predicted that hydraulic displacement would effectively mobilize DNAPL for recovery at spacings up to 120 feet. Since candidate well spacings of only 25 and 50 feet are considered by this RA, hydraulic displacement is expected to effectively recover mobile DNAPL in the saturated UBA for removal. Although hydraulic displacement relies on fluid flow through permeable saturated soils, steam injection (RA 5a) is equally reliant on this Site condition. Similarly, although a thorough understanding of DNAPL distribution is important to the evaluation of a hydraulic displacement remedy, it is at least equally important to the evaluation of a steam injection remedy, if not more so.

The SVE component of this RA also reduces the volume (and mass) of hazardous constituents in the unsaturated zone and the toxicity of unsaturated zone soils and soil gas. VOCs, including the volatile fraction of DNAPL (i.e., MCB), are extracted from the subsurface by SVE. DNAPL mobility in the unsaturated zone is also reduced by volatilization of the MCB component since the DDT component of the DNAPL will sorb strongly to soil and is relatively immobile in the environment. ***Rank: Reduces Toxicity, Mobility, and Volume (significantly reduces mobility in short-term).***

Short-Term Effectiveness. RA 4 is effective in protecting human health and the environment in the short-term. Under this RA, groundwater and DNAPL are extracted from the subsurface for ex-situ handling. DNAPL would be separated from groundwater and temporarily accumulated at the Property pending off-Site transport and disposal. Groundwater would be filtered and re-injected into the UBA to enhance hydraulic gradients. Engineering controls would be provided to ensure the protection of human health and the environment in the short-term during DNAPL and groundwater handling. DNAPL would be accumulated in a dual-contained tank with engineering controls to prevent over-filling and automatically detect leaks. Secondary containment with leak detection would also be provided for the groundwater handling system to effectively prevent releases of contaminated groundwater to surface. No ex-situ dissolved-phase contaminant treatment system is required for this RA. During installation of the multiphase extraction and groundwater injection wells, safe-work procedures would be employed to protect the health of on-site workers and prevent release of any VOCs, nuisance odors, or dust.

The short-term effectiveness of the SVE component is the same as for RA 3. Disposable carbon/resin would be the lowest cost ex-situ treatment technology for soil vapors and would effectively treat vapor-phase contaminants in compliance with air emission ARARs. VOC migration in soil gas would be controlled by SVE during remedy implementation. ***Rank: Effective.***

Implementability. As described in Section 5.2.4, this RA is implementable, and field pilot testing has demonstrated the feasibility of removing DNAPL at a moderate rate by hydraulic displacement. Extraction wells can be installed using standard drilling methods and equipment. Standard separation techniques can be used to separate the Montrose DNAPL from groundwater. Specialized field equipment or contractors are not required for this RA. Precipitate fouling of the extraction pumps/piping was observed during the extraction pilot test, but such fouling effects could be abated through routine maintenance during operations. Routine well redevelopment would be implemented to restore hydraulic conductivities of the extraction and injection wells. Administratively, the re-injection limits specified in the groundwater ROD would need to be waived in order to implement the RA (which was approved for the 2004/2005 extraction test). ***Rank: Implementable.***

Cost. The estimated cost of RA 4 is $11.7 MM NPV as shown in Table 6.1 and Appendix J. The cost of RA 4 includes installing and operating 18 extraction and 23 injection wells on a 50-foot spacing, including the isolated area surrounding boring SSB-12. For a 25-foot spacing, a total of 32 extraction and 37 injection wells would be required, increasing the estimated cost of this RA to $13.0 MM NPV.

Hydraulic displacement costs were previously estimated and submitted to EPA in November 2007 (Earth Tech, 2007e). Hydraulic displacement costs were subsequently revised in accordance with EPA cost reconciliation discussions held in February 2008. Budgetary price quotations were obtained from subcontractors and equipment vendors to increase the relative accuracy and reliability of these remedy cost estimates.

The duration of the remedy is assumed to be 8 years total based on the following schedule of activities:

- Year 1 = Design
- Year 2 = Construction
- Years 3-7 = O&M (5 years)
- Year 8 = Verification and Abandonment

The amount of DNAPL recovery is assumed to be highest in the first year of O&M, with DNAPL recovery decreasing each successive year. No ex-situ treatment of groundwater is assumed for this RA other than physical separation. The cost of the institutional controls and SVE components of this RA are identical to RAs 2 and 3 respectively. ***Rank: Moderate ($11.7 MM NPV).***

State Acceptance. This criterion will be discussed in more detail once comments on the Final DNAPL FS are received from the State. EPA will address this criterion in the ROD. However, it is noted that this RA has a relatively small carbon footprint, which may be favorable to the State. ***Rank: Not Applicable.***

Public Acceptance. RA 4 may be accepted by the public because it is protective of human health and reduces DNAPL mass in the long-term by hydraulic containment and dissolution. The mobility of the DNAPL is significantly reduced by this RA, increasing the environmental protectiveness and, potentially, public acceptance. Groundwater and DNAPL would be handled ex-situ but not treated. The reduced amount of infrastructure (relative to RAs 5a and 6a) and injection of filtered groundwater back into the UBA is expected to be acceptable to the public. Under this RA, all groundwater extracted from the UBA at the Property would be re-injected back into the UBA at the Property thus preserving the groundwater resource. No groundwater would be re-injected off-Property under this RA. Since groundwater is not being discharged to the storm drain or industrial sewer, there is no potential for contamination of those water routes. This RA involves no thermal processes, and there is no potential for release of contaminated steam or heated vapors to atmosphere. This RA has a reduced risk of uncontrolled DNAPL migration relative to RA 5a and would use significantly less energy than both RAs 5a and 6a.

The public acceptance of the institutional control and SVE and components of this RA would be the same as for RAs 2 and 3 respectively. Institutional controls restricting Site use and activities that pose a risk of exposure to DNAPL-impacted soil are expected to be acceptable to the public. Removal of VOCs by SVE from permeable unsaturated soils will increase the protectiveness of the RA and is expected to be acceptable to the public. The public is also expected to accept use of disposable carbon/resin for on-Site treatment of soil vapors extracted by SVE over the other two candidate treatment technologies as discussed in Section 6.2.3. The energy consumption, carbon footprint, and greenhouse gas emissions from this RA would be relatively low (significantly lower than for RAs 5a and 6a), which may be favorable to the public. RA 4 removes both DNAPL-phase MCB and DDT from the subsurface. Hydraulic displacement does not significantly change the DNAPL architecture, allowing removal of liquid-phase DNAPL including the DDT component. ***Rank: May Be Accepted.***

6.2.5 Remedial Alternative 5a – Steam Injection over Focused Treatment Area

This RA includes four GRAs: (1) Steam injection over a focused treatment area, (2) SVE in the unsaturated zone, (3) institutional controls, and (4) containment in the saturated zone as required by the Groundwater ROD.

Overall Protection of Human Health and the Environment. Similar to other RAs, the remedies for soil and groundwater are expected to limit contaminant exposure pathways thereby protecting human health. Exposure to contaminants at surface will be addressed by the remedy for soil, and exposure to dissolved-phase contaminants are addressed by the remedy for groundwater. The extent of DNAPL is fully within the TI Waiver Zone. The institutional controls component of this RA provides additional protectiveness by restricting Site access and uses that may result in exposure to DNAPL-impacted soils.

This RA protects the environment by removing DNAPL mass (via steam injection) within a focused treatment area where the majority of the DNAPL mass (and all of the mobile DNAPL) is located within the UBA. Although some residual DNAPL mass will be left in place following steam injection, the hydraulic containment component of RA 5a (required by the remedy for groundwater) protects the environment by controlling migration of contaminants in the dissolved-phase and reducing DNAPL mass in the long-term by dissolution. The SVE component of RA 5a additionally protects human health and the environment by removing the source of VOCs/DNAPL in the unsaturated zone and controlling VOC migration in soil gas in the short-term. However, it is noted that VOCs will be left in place within the low permeability PD soils (4 to 25 feet bgs), where SVE is significantly less effective.

Also, a significant amount of greenhouse gases (an estimated 46 million pounds) would be emitted to the environment as a result of this RA, contributing to harmful impacts on the environment, including global warming. California law recognizes that the potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the State from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other human health-related problems (Health & Safety Code §38501(a)).

As described in Section 5.2.6, steam injection presents an increased risk of contaminant migration. Uncontrolled steam distribution can result in lateral spreading and a reduction in the protectiveness of this RA. For example, if lateral spreading were to occur to the north and underneath the adjacent commercial building at the former Boeing Realty Corporation property, this RA may not be as protective of human health. The well spacing proposed by EPA for steam injection (60 feet) is larger than the well spacing for hydraulic displacement (25 to 50 feet), and as a result, there is a greater potential of not fully recovering displaced or mobilized contaminants under RA 5a. Additionally, there is an increased risk of downward migration associated with steam injection. Steam injection is a displacement technology, which will displace liquid-phase DNAPL, concentrating it at the steam front and increasing its mobility in the environment. If not effectively recovered, the DNAPL may migrate downward into the BFS. Dissolved-phase contaminants can also be mobilized either laterally or downward if steam condensate is not effectively recovered, which would fail to comply with RAOs. This RA includes implementation of a hot floor within the underlying BFS in an effort to reduce the risks of downward migration. However, the effectiveness of a steam injection hot floor in the underlying aquifer is uncertain and has not been implemented at a comparable site. Although steam was injected into an underlying aquifer unit (the Deep Aquifer) at the SCE Site in Visalia, California, the primary reason was to prevent the upward flow of cool groundwater into the overlying thermal treatment zone. Additionally, only a small portion of the hot floor at the SCE Site was heated, using just three steam injection wells. By comparison, 26 steam injection wells would be required for the hot floor at the Montrose Site under RA 5a. Furthermore, there are negative environmental impacts associated with a hot floor, including higher energy consumption, higher carbon footprint and greenhouse gas emissions, and increased risk of downward migration from drilling through DNAPL-impacted soils.

The condensed steam will become contaminated as it contacts DNAPL and has the potential to vertically migrate downward as well. While the mass of dissolved MCB in condensed steam would be substantially lower than DNAPL, it still has the potential to impact the BFS in concentrations significantly higher than what is currently present in the BFS. ***Rank: Protective (but higher risks).***

Compliance with ARARs. RA 5a would have to comply with the most ARARs of all RAs under consideration. The institutional controls component of this RA would comply with Land Use Covenant requirements under CCR Title 22 and the California Civil Code. The SVE component of this RA would need to comply with federal and state ARARs related to air quality including the Clean Air Act and SCAQMD regulations. A steam boiler is required for this RA and would also need to comply with the above-referenced air emission standards. This RA would generate solid waste including soil cuttings, decontamination water, PPE, DNAPL, boiler brine waste, and spent carbon, and would need to comply with regulations governing waste classification, management, and disposal including CFR Title 40 and CCR Title 22. This RA would also have to comply with local municipal codes related to system construction. Steam injection, multiphase extraction, and temperature monitoring wells installed under this RA would need to comply with California Well Standards. Separate-phase DNAPL is also temporarily accumulated on-Site (pending disposal) under this RA, and therefore, the aboveground accumulation tank would have to comply with regulations for hazardous materials accumulation, including CFR Title 40 and CCR Title 22. Re-injection of treated groundwater into the BFS and Gage Aquifer off-Property would comply with Groundwater ROD in-situ groundwater standards.

As described in Section 5.1.6, the carbon footprint of RA 5a is estimated at 46 million pounds of greenhouse gases, requiring approximately 297,400 trees to offset the carbon dioxide production (Table 5.1 and Appendix H), and is the highest carbon footprint of all the RAs under consideration. This high energy demand RA does not comply with EPA green remediation initiatives or advance the goals of the California Global Warming Solutions Act of 2006. If a thermal remedy were implemented at both the Montrose and Del Amo Superfund Sites, the combined GHG emissions would have an even more significant conflict with State and Federal efforts to reduce GHG emissions. Additionally, there is an increased risk of excursions, upset conditions, or fugitive emissions under this thermal remediation RA, which may not comply with ARARs. ***Rank: Complies (but not with global warming ARARs).***

Long-Term Effectiveness and Permanence. Long-term effectiveness is accomplished through dissolution and the hydraulic containment component of this RA. Any mass that is present in the BFS is also expected to be reduced to a level that meets ARARs within the containment timeframe. Under this RA, DNAPL mass (both mobile and residual) is reduced by steam injection in the saturated UBA over a focused treatment area. However, steam injection will not remove all of the DNAPL mass from within the focused treatment area. Some residual DNAPL will be left in-situ, both inside and outside the focused treatment area, and will serve as a continuing source of dissolved-phase contamination to groundwater. Consequently, the required duration of long-term containment is not meaningfully reduced by this high cost source area RA (i.e., from 4,900 to 4,400 years). The SVE component of this RA would reduce the VOC/DNAPL mass in the permeable unsaturated zone to a level that significantly reduces the future risk to the underlying groundwater from contaminant leaching, although VOCs would remain in place within the low permeability PD soils (4 to 25 feet bgs). The permanence of the remedy is improved by removal of VOC/DNAPL mass from both the unsaturated and saturated zones, but ultimately, an insufficient amount of mass can be removed to significantly reduce the required duration of hydraulic containment in the long-term. ***Rank: Effective (but higher risks).***

Reduction of Toxicity, Mobility, and/or Volume of Hazardous Constituents. The SVE component of this RA would reduce the volume (and mass) and toxicity of hazardous constituents in the unsaturated zone. The mobility of DNAPL in the unsaturated zone would also be reduced by volatilization of the

MCB component. The DDT component of the DNAPL will sorb strongly to soil and is relatively immobile in the environment.

RA 5a reduces the volume and toxicity of DNAPL in the saturated zone within a focused treatment area where approximately 60% of the DNAPL mass at the Site is located (i.e., an estimated 473,700 pounds). DNAPL volume is reduced by either (a) steam flushing of liquid-phase DNAPL to multiphase extraction wells, or (b) volatilization of the MCB component of the DNAPL. A portion of the liquid-phase DNAPL will be displaced at the steam front and potentially recoverable under this RA. However, it is noted that less than 1% of the PCE DNAPL was recovered as a separate-phase during full-scale steam injection at the Savannah River Site in Aiken, South Carolina. Other than recovered liquid-phase DNAPL, the DDT component of the DNAPL would remain in-situ following steam injection. Assuming that the MCB represents 50% of the DNAPL mass, an estimated 236,800 pounds of MCB is present in the focused treatment area and potentially subject to thermal remediation (although only a portion of this estimated mass would be recovered by steam injection). Assuming that 80% of the MCB mass in the focused treatment area were removed by thermal remediation, then an estimated 189,500 pounds of MCB would be removed. Given the characteristics of the Montrose Site, removal of even 80 percent of the DNAPL mass is considered an optimistic assumption for mass removal at the Site. The potential effectiveness of thermal remediation at the site is highly uncertain given the complex geologic setting with pooled DNAPL, the highly layered and heterogeneous aquitard, the unique DNAPL composition, and the thickness of the saturated treatment zone. Some DNAPL will be left in place following steam injection, but is expected to be at residual levels and relatively immobile in the environment. An estimated 284,200 pounds of MCB and DDT (primarily DDT) will be left within the focused treatment area following steam injection. Residual MCB will serve as a continuing source of groundwater contamination but will be reduced in the long-term by dissolution and the hydraulic containment component of the RA.

The ability of steam injection to reduce the volume of DNAPL at the Site has not been pilot tested and is uncertain. The saturated UBA is highly layered, and steam injection is dependent on permeable soils for delivery of steam to the treatment area. Steam will preferentially flow through the higher permeability sand layers, and heating of the less permeable soils may be problematic. For this reason, steam injection was not assembled into a formal RA at the Del Amo Superfund Site where the lithology of at least one NAPL-impacted area is similar to the Montrose Site (URS, 2008). The rationale for excluding a formal steam injection alternative was that the low permeability and heterogeneous nature of the aquitard soils were not well suited for application of steam injection. Additionally, groundwater influx from outside the focused treatment area may inhibit the effectiveness of steam injection in reaching target temperatures. Even at sites where considerable effort has gone into thermal pilot testing, extensive computer modeling, design work, and technical review, there remains considerable uncertainty regarding performance of thermal remedies. For example, it has taken many years for the TEE steam injection pilot to be implemented at the Williams Air Force Base, and yet the US Air Force predicts that considerable LNAPL volume will be left in place following the thermal remedy.

Steam injection has never been applied to a DNAPL site where either MCB or DDT was a primary component of the DNAPL (i.e., unique and untested DNAPL). DDT precipitation and mineral fouling, during volatilization of the MCB component, could plug the soil pores and reduce the effective permeability of the UBA soils. Because steam injection temperatures would exceed the melting point of DDT (108.5°C at 1 atmosphere), liquid-phase DDT may be mobilized by the steam injection, either laterally or vertically downward, which is contrary to the RAOs. Some MCB may also remain in solution with the liquid-phase DDT and be carried with it. Once the liquid-phase DDT cools to temperatures below the melting point, it would precipitate as a solid and be relatively immobile in the environment. However, mobilization of the DDT in the subsurface at temperatures above the melting point is a possibility during steam injection.

The co-boiling point of the Montrose DNAPL (96°C) is relatively high in comparison with other VOCs and approaches the boiling point of water (100°C). A subsurface temperature of 96°C would be required to initiate co-boiling in the subsurface (at atmospheric pressure), and temperatures would need to be maintained above 96°C to reduce the volume of MCB in the subsurface. By comparison, benzene and TCE co-boil at temperatures of only 69°C and 73°C respectfully. At several steam injection sites, the contaminant types are not comparable to the Montrose Site such as the creosote DNAPL at the SCE Visalia Site and Pacific Wood Treating Site or such as the jet fuel LNAPL at the Williams Air Force Base OU2 Site. SCE reported that the creosote became an LNAPL at temperatures greater than 50°C, eliminating concerns associated with downward migration at these sites. The potential for steam injection to reduce DNAPL-phase MCB mass has not been demonstrated at a comparable site. 2-Dimensional bench testing suggests that the removal efficiency for the Montrose DNAPL may be lower than observed at some other sites where NAPLs have lower boiling and co-boiling points.

In spite of the relatively high co-boiling point, the amount of steam to be injected as part of this RA was reduced to between 2 and 3 pore volumes in response to EPA comments during cost reconciliation. These pore volumes of equivalent cold water flushing represent the low and high energy balance scenarios. However, lower energy and steam delivery to the saturated UBA may result in lower reductions in DNAPL mass/volume. The DNAPL-impacted soils must be heated to the target temperature and held at that temperature for a sufficiently long time as to volatilize the MCB component of the DNAPL (not otherwise flushed by the steam front). By way of comparison, the Savannah River Site has been identified as a large-scale steam injection project, with PCE and TCE as the primary component of the DNAPL. The co-boiling point of PCE/TCE/water mixture (<88°C) is below that of the Montrose DNAPL. At the Savannah River Site, steam has been injected for a period of 40 months (3.3 years), and according to Savannah River Site personnel, the amount of steam injected into the subsurface is approximately 2.5 times the model-predicted amount. Had steam injection been terminated at the target energy consumption, less than 60% of the DNAPL removed to date would have been recovered from the Savannah River site. Similarly, steam was injected at the SCE Visalia Site for a duration of 3 years, and SCE has reported that "approximately 8" pore volumes of steam were flushed through the primary DNAPL-impacted aquifer (the Intermediate Aquifer). Additionally, a very high rate of steam was injected at the Visalia Site, approximately 5 times higher than what has been considered for the Montrose Site. If only 2 to 3 pore volumes of steam flushing were used at the Montrose Site, the removal efficiencies would be significantly less, considering the lithology at the Montrose Site is significantly less favorable to steam injection than the lithology at either the Savannah River Site or SCE Visalia Site. At both sites, steam was injected into a sand aquifer that is 25 to 30 feet thick. At the SCE Visalia Site, the Intermediate Aquifer was described as a medium to coarse-grained sand with some gravel, which is significantly better suited to steam injection than the saturated UBA at the Montrose Site. ***Rank: Reduces Toxicity, Mobility, and Volume (mobility increased in short-term).***

Short-Term Effectiveness. RA 5a may be effective in protecting human health and the environment in the short-term, but it has the greatest potential (of the RAs considered) for remedy excursions or upset conditions. Under this RA, liquid-phase DNAPL is flushed for extraction, and the MCB component of the DNAPL is volatilized and extracted for ex-situ treatment. Displaced DNAPL, contaminated steam condensate, and heated MCB vapors must be effectively recovered in order to prevent contaminant migration in the subsurface, either laterally outside the focused treatment area or downward into the underlying BFS. Contaminant migration underneath the adjacent commercial building located at the former Boeing Realty Corporation property would reduce the protectiveness of this RA in the short-term. Compared with ERH and hydraulic displacement, steam injection has a lower well density, and therefore, has the greatest risk of not effectively recovering all mobilized contaminants during remedy implementation. There is additionally an increased mobilization risk associated with installation of the 36 hot floor wells under this RA. To install a hot floor well, a boring must be advanced through the DNAPL-impacted zone to the very base of the UBA and extreme care must be exercised to prevent DNAPL migration as a result of drilling activities. While use of drilling muds and conductor casings are often effective in preventing cross-communication, there is nonetheless an increased risk of downward migration occurring during drilling or after drilling and behind well casing. Downward migration of DNAPL as a result of installing hot floor wells would not be protective of the environment in the short-term.

The short-term effectiveness of the ex-situ vapor treatment system and SVE component of this RA would be similar to RA 3. However, due to the increased VOC mass removal, disposable carbon/resin would no longer be the most cost-effective. One of the other two ex-situ vapor treatment technologies would be used for this RA, and steam-regenerable carbon/resin is assumed for purposes of estimating cost and remedy evaluation in this FS. Spent carbon would be regenerated on-Site using low pressure steam, cooled using air, and placed back into service. The steam and recovered VOCs would be condensed and separated. The recovered VOCs (DNAPL) would be temporarily accumulated on-Site pending disposal within 90 days of generation. The condensed steam would be combined with extracted groundwater and treated on-Site using carbon and advanced oxidation (i.e., HiPOx™). The steam-regenerable carbon/resin would be effective in protecting human health and the environment in the short-term but is a more complex system requiring an increased level of maintenance and oversight. Secondary containment would be required for the system to prevent accidental releases of steam condensate, groundwater, or DNAPL to the ground surface or stormwater pathway. Engineering controls would be required to automatically terminate system operations to ensure compliance with air quality standards, to prevent over-filling of the temporary accumulation tanks, or if leaks were detected within the secondary containment.

In addition, there is an increased potential for fugitive emissions during remedy implementation as compared with other alternatives. Heated vapors and steam will be recovered during remedy implementation for ex-situ treatment. The potential for fugitive emissions increases as a result of handling heated vapors and contaminated steam, either through accelerated corrosion or pipe fittings/threads. Due to the pressures associated with steam injection, containment of the heated vapors and steam during remedy implementation can be problematic. For example, the plastic piping materials (CPVC) used at the Silresim Superfund Site and Cape Fear Wood Preserving Site suffered a complete loss of mechanical integrity during ERH pilot testing, releasing heated vapors and steam to atmosphere. Similarly, contaminated steam or vapors can escape to surface through previously abandoned borings or wells that are not able to withstand the elevated temperatures associated with this RA. For example, at the SCE Visalia site, one well suffered a catastrophic failure due to incompatibility of the bentonite annular seal materials with the elevated temperatures of the full-scale steam remedy (Lawrence Livermore National Laboratory, 1999). Steam flow to surface was so significant that it dispersed sediment up to 200 feet from the well, a portion of which impacted off-site areas. It may be necessary to re-abandon several former soil borings or replace some existing wells in order to prevent the release of fugitive emissions into the atmosphere during remedy implementation. Routine inspection of the aboveground soil vapor piping and equipment would be required during remedy implementation to detect and subsequently correct any fugitive emissions of heated soil vapors or steam. Fugitive emissions, if any, during remedy implementation would reduce the protectiveness of this RA in the short-term. RA 5a would additionally include air emissions from the steam boiler (nitrogen and sulfur oxides). RA 5a would also consume a large amount of energy and result in a significant amount of greenhouse gas emissions, the most of any RA under consideration. ***Rank: Potentially Effective (but higher risks).***

Implementability. As described in Section 5.2.6, this steam injection RA would be difficult to implement. A significant amount of above- and below-ground infrastructure would be required to generate and deliver steam throughout the focused treatment area. A large number of UBA wells (up to 55 combined steam injection, multiphase extraction, and temperature monitoring) would be required and would generate a significant amount of waste, including the isolated area surrounding boring SSB-12. This RA additionally includes implementation of SVE in the unsaturated zone, ex-situ vapor treatment, and ex-situ groundwater treatment. The groundwater under this RA would require ex-situ treatment for re-injection into the BFS and Gage through the Groundwater Remedy Treatment System. Re-injection of the treated groundwater into the UBA would potentially cool the subsurface and be counter-productive to the thermal remedy. The re-injection flow requirement of the DNAPL remedy would need to be considered during design of the Groundwater Remedy Treatment System to accommodate this additional quantity of water. Additionally, implementation of a hot floor in the underlying BFS would be required to attempt to reduce the risks associated with downward migration of DNAPL and steam condensate, although hot floors are difficult to implement and very infrequently implemented. This RA would require highly skilled operators and the highest level of maintenance of all RAs under consideration, including boiler maintenance, water conditioning, and brine disposal. Steam injection is not implemented as frequently as other thermal remediation technologies and has been abandoned as a commercial technology by some vendors. A lack of qualified commercial steam injection vendors would limit the implementability of this RA. Furthermore, the lack of vendor experience in treating the unique Montrose DNAPL and injecting steam into a complex, layered, and low permeability aquitard would further limit the implementability of this RA.

Montrose consulted with a relatively large number of technical experts, many of whom have previously participated in EPA advisory panels, in reviewing steam injection as a candidate remedial technology. The technical experts unanimously indicated that ERH and ISTD are the thermal technologies of choice today, and that steam injection is not being implemented as frequently. ERH and ISTD offer technical advantages over steam injection because they are not as dependent on permeability and do not present the same downward mobilization risks resulting from steam condensate generation and concentration of the DNAPL at the steam front. Heating of the subsurface is also more controlled under ERH and ISTD, while steam injection can be prone to displacement or uncontrolled steam flow along preferential permeability pathways, resulting in contaminant spreading. ERH and ISTD also do not require a steam boiler, conditioning of the water fed to the boiler, or management of boiler brine waste. Currently, there are only four active steam injection sites in the United States: (1) the Pacific Wood Treating Site in Port of Ridgefield, Washington, (2) the Savannah River M-Area Settling Basin Site in Aiken, South Carolina, (3) the Williams Air Force Base OU2 Site in Mesa, Arizona, and (4) the Northrop (formerly TRW) Site in Danville, Pennsylvania. Additionally, CH2M Hill has referenced the SCE Visalia Site, where a full-scale steam injection remedy was implemented, as being comparable to the Montrose Site (CH2M Hill, 2007). However, none of these sites are comparable to the Montrose Site for the reasons identified in Sections 5.2.6 and Appendix L and should not be considered during evaluation of RA 5a. There are fundamental differences between these sites and the Montrose Site which preclude their consideration as precedents for evaluation of steam injection under RA 5a, including contaminant type, lithology, steam injection rate, duration/pore volumes, hot floor, steam/energy source, and remedy funding. ***Rank: Difficult To Implement.***

Cost. The estimated cost of RA 5a is $24.6 to $25.8 MM NPV as shown in Table 6.1 and Appendix J, which varies depending on the assumptions related to the energy demand. As described in Section 5.1.6, the cost of this RA includes up to 14 steam injection, 27 multiphase extraction wells, and 14 temperature monitoring points, including the isolated area surrounding SSB-12.

Steam injection costs were previously estimated and submitted to EPA in November 2007 (Earth Tech, 2007f). Following cost reconciliation discussions in December 2007 and January 2008, steam injection costs were revised and resubmitted to EPA in July 2008 (Earth Tech, 2008d). Steam injection costs were revised a second time following additional EPA comments (EPA, 2008a). Budgetary price quotations were obtained from subcontractors and equipment vendors, as indicated in Appendix J, to increase the relative accuracy and reliability of these remedy cost estimates.

An estimated cost range is provided for RA 5a based on the energy balance provided in Appendix H. As a result of cost reconciliation discussions with EPA, steam injection costs were estimated based on both a lower and higher energy demand. The lower energy demand was based on 2 pore volumes of steam flushing, while the higher energy demand was based on 3 pore volumes of steam flushing. Because the hot floor in the BFS would be implemented slightly in advance of heating the UBA (and due to higher groundwater influx), the energy demand range assumed for the hot floor was 2.5 to 3.5 pore volumes.

The duration of the remedy is assumed to be 4 years total based on the following schedule of activities:

- Year 1 = Design
- Year 2 = Construction
- Year 3 = O&M (1 year)
- Year 4 = Verification and Abandonment

A duration of 1 year has been assumed for steam injection over the focused treatment area based on cost reconciliation discussions with EPA. Soil vapors are assumed to be treated using steam-regenerable carbon instead of disposable carbon due to the increased VOC mass removal under this RA. Ex-situ treatment of groundwater is additionally included and reflects a combination of disposable carbon and advanced oxidation (i.e., HiPOx™). The cost of the hydraulic containment and institutional controls components is identical to RA 2. However, the estimated steam injection cost includes SVE within the unsaturated UBA (45 to 60 feet bgs), and thus the SVE component was reduced to reflect only SVE within the PVS from approximately 25 to 45 feet bgs.

SCE reported that approximately 8 pore volumes of steam flushing were required at the Visalia, California Site. If up to 8 pore volumes of steam flushing were required at the Montrose Site, then the steam remedy costs assuming only 2 to 3 pore volumes of flushing would be greatly under-estimated. Given the heterogeneous UBA and complicated DNAPL architecture, the Montrose Site may require more pore volumes of steam flushing than the SCE Visalia Site, not less. If up to 8 pore volumes of steam flushing were required, the duration of RA 5a would be increased from 1 to 2 years resulting in a cost increase of $8 MM NPV ($32.6 to $33.8 MM NPV total cost). The increased natural gas consumption from the additional steam flushing would also increase the carbon footprint from approximately 46 to 80 million pounds of greenhouse gases (a 74% increase in the GHG emissions). Further, climate change regulation is expected to increase the costs of both natural gas and electricity because upstream suppliers of these commodities are expected to be regulated at both the State and Federal level. In other words, as a price is placed on carbon emissions, whether directly via a carbon tax or, more likely, indirectly via State and/or Federal cap-and-trade regimes, the cost of carbon-intensive forms of energy (e.g., natural gas and non-renewably generated electricity) will increase. Such increased costs would add additional cost to this RA.

As indicated in Section 6.2.1, the cost of long-term hydraulic containment is estimated at $1.1 MM NPV for containment costs incurred after Year 50 (projected end of groundwater remedy). Using a discount rate of 4%, it is noted that costs incurred after approximately Year 350 do not contribute at all (not even $1) to the NPV total. As a result, there is no difference in the NPV cost of long-term hydraulic containment between estimated timeframes of 4,400, 4,600, or 4,900 years. Unless the timeframe is below approximately 350 years, the NPV cost of long-term hydraulic containment would remain unchanged.

The cost of source depletion under RA 5a ($24.6 to $25.8 MM NPV) is significantly higher than the cost of long-term hydraulic containment ($1.1 MM NPV). This relationship in RA costs was identified as one of the decision-making criteria regarding DNAPL source depletion by an expert panel in 2003, *The DNAPL Remediation Challenge: Is There a Case for Source Depletion* (EPA, 2003). When containment costs are significantly less than the cost of source depletion, the expert panel advises that source depletion may not be needed. As indicated in Section 5.2.2, if all decision criteria established by the expert panel were considered, the conclusion for the Montrose Site would be that source depletion is not needed. There is little cost benefit of implementing a $24.6 to $25.8 MM NPV source zone depletion remedy if long-term hydraulic containment will still be required for an estimated 4,400 years. Overall, RA 5a is a high cost remedy and is not cost-effective because it does not meaningfully reduce hydraulic containment timeframes. ***Rank: High Cost ($24.6 to $25.8 MM NPV).***

State Acceptance. This criterion will be discussed in more detail once comments on the Final DNAPL FS are received from the State. EPA will address this criterion in the ROD. However, the relatively high GHG emissions associated with this RA may not be favorable to the State. ***Rank: Not Applicable.***

Public Acceptance. Of the RAs under consideration, RA 5a includes the greatest amount of infrastructure, complexity, uncertainty, energy demand, greenhouse gas emissions, and mobilization risk, and therefore, is expected to be the least acceptable to the public. A large amount of above- and below-ground infrastructure would be required to implement this steam injection remedy including a moderately large natural gas-fired steam boiler and associated water conditioning system and brine waste transfer equipment. A significant amount of natural gas would be required to implement this RA (163,000 to 244,000 MCF), resulting in the highest energy usage and carbon footprint of all RAs under consideration (46 million pounds of greenhouse gases). The carbon footprint for RA 5a is approximately three times the carbon footprint for RA 6a and ten times the carbon footprint for RA 4. Despite the high carbon footprint and high remedy costs, this RA would leave a significant amount of contaminant mass, both within the focused treatment area (284,200 pounds; primarily DDT), and outside the focused treatment area (322,400 pounds). Preferential removal of the MCB component of the DNAPL, leaving the DDT component behind, may not be acceptable to the public.

Steam injection within the focused treatment area would generate heated soil vapors, which would be extracted for ex-situ treatment. With thermal remediation projects, there is an increased potential for accidental releases of heated vapors or contaminated steam to atmosphere. The higher temperatures and pressures associated with this RA can result in aboveground piping failure or accelerated corrosion. Additionally, the subsurface will remain hot even if remediation system operations are interrupted. VOC vapors would continue to be generated in-situ even with the remediation system off. Long periods of system downtime, without adequate soil vapor recovery, have the potential to cause VOC migration in the unsaturated zone. VOCs not effectively recovered during implementation of this RA will re-condense in cool areas of the Site, potentially outside of the treatment area footprint. Following treatment, the subsurface may remain hot for years, posing a VOC migration risk far beyond the duration of the thermal remedy.

This RA will additionally mobilize and concentrate liquid-phase DNAPL at the steam front, increasing the migration risk both laterally and vertically. The injected steam will also condense in the subsurface and must be effectively recovered in order to prevent migration of dissolved-phase contaminants. Ex-situ treatment of groundwater and steam condensate would be required and would be re-injected off-Property into the BFS and Gage Aquifer, instead of the UBA, following treatment. Re-injection of the treated groundwater into the UBA would cool the subsurface and be counter-productive to the thermal remedy. The increased infrastructure, complexity, energy demand, greenhouse gas emissions, and mobilization risk associated with this RA, as compared with other RAs, may not be acceptable to the public. As previously discussed, high energy demand and greenhouse gas emissions have historically been significant public concerns.

This RA would additionally require ex-situ treatment of soil vapors at a flow rate approximately twice that required for RAs 3 and 4. Due to the increased VOC mass removal under this RA, disposable carbon/resin would no longer be the most cost-effective ex-situ vapor treatment technology. Instead, one of the other two vapor treatment technologies, which may be less acceptable to the public, would be required under this RA. The public acceptance of the institutional control component of this RA would be the same as for RA 2. Institutional controls restricting Site use and activities, with the potential for exposure to DNAPL-impacted soils, are expected to be acceptable to the public. ***Rank: May Not Be Accepted.***

6.2.6 REMEDIAL ALTERNATIVE 6A – ERH OVER FOCUSED TREATMENT AREA

This RA includes four GRAs: (1) ERH over a focused treatment area, (2) SVE in the unsaturated zone, (3) institutional controls, and (4) containment in the saturated zone as required by the Groundwater ROD.

Overall Protection of Human Health and the Environment. Similar to other RAs, the remedies for soil and groundwater are expected to limit contaminant exposure pathways thereby protecting human health. Exposure to contaminants at surface will be addressed by the remedy for soil, and exposure to dissolved-phase contaminants are addressed by the remedy for groundwater. The extent of DNAPL is fully within the TI Waiver Zone. The institutional controls component of this RA provides additional protectiveness by restricting Site access and uses that may result in exposure to DNAPL-impacted soils.

Similar to RA 5a, this RA protects the environment by removing DNAPL mass (via ERH) within a focused treatment area where the majority of the DNAPL mass (and all of the mobile DNAPL) is located within the UBA. Although some residual DNAPL mass will be left in place following ERH, the hydraulic containment component of RA 6a (required by the remedy for groundwater) protects the environment by controlling migration of contaminants in the dissolved-phase and reducing DNAPL mass in the long-term by dissolution. Some mobilization risks are associated with this RA, such as failure to recover all heated soil vapors. Recovery of contaminant vapors is fundamental to the effectiveness of ERH, and unrecovered vapors may migrate to cooler areas, potentially outside of the remediation footprint, and re-condense. However, the risks are less than for RA 5a and are reduced by the high density of wells required for ERH implementation. The SVE component of RA 6a additionally protects human health and the environment by removing the source of VOCs/DNAPL in the unsaturated zone and controlling VOC migration in soil gas in the short-term. However, as with all RAs, it is noted that VOCs will be left in place within the low permeability PD soils (4 to 25 feet bgs), where SVE is significantly less effective.

Also, a significant amount of greenhouse gases (an estimated 14 million pounds) would be emitted to the environment as a result of this RA, contributing to global warming. California law recognizes that the potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the State from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other human health-related problems (Health & Safety Code §38501(a)). ***Rank: Protective (but higher risks).***

Compliance with ARARs. RA 6a would comply with DNAPL ARARs. The institutional controls component of this RA would comply with Land Use Covenant requirements under CCR Title 22 and the California Civil Code. The SVE component of this RA would need to comply with federal and state ARARs related to air quality including the Clean Air Act and SCAQMD regulations. This RA would generate solid waste including soil cuttings, decontamination water, PPE, DNAPL, and spent carbon, and would need to comply with regulations governing waste classification, management, and disposal including CFR Title 40 and CCR Title 22. This RA would also have to comply with local municipal codes related to system construction. ERH electrodes, multiphase extraction, and temperature monitoring wells installed under this RA would need to comply with California Well Standards. Separate-phase DNAPL is also temporarily accumulated on-Site (pending disposal) under this RA, and therefore, the aboveground accumulation tank would have to comply with regulations for hazardous materials accumulation, including CFR Title 40 and CCR Title 22. Re-injection of treated groundwater into the BFS and Gage Aquifer off-Property would comply with Groundwater ROD in-situ groundwater standards.

As described in Section 5.1.8, the carbon footprint of RA 6a is estimated at 14 million pounds of greenhouse gases, requiring approximately 88,500 trees to offset the carbon dioxide production (Table 5.1 and Appendix H), and is the second highest carbon footprint of all the RAs under consideration. This high energy demand RA does not comply with EPA green remediation initiatives or advance the goals of the California Global Warming Solutions Act of 2006. If a thermal remedy were implemented at both the Montrose and Del Amo Superfund Sites, the combined GHG emissions would have an even more significant conflict with State and Federal efforts to reduce GHG emissions. Additionally, there is an increased risk of excursions, upset conditions, or fugitive emissions under this thermal remediation RA, which may not comply with ARARs. ***Rank: Complies (but not with global warming ARARs).***

Long-Term Effectiveness and Permanence. Long-term effectiveness is accomplished through dissolution and the hydraulic containment component of this RA. Any mass that is present in the BFS is also expected to be reduced to a level that meets ARARs within the containment timeframe. Under this RA, DNAPL mass (both mobile and residual) is reduced by ERH in the saturated UBA over a focused treatment area. However, ERH will not remove all of the DNAPL mass from within the focused treatment area. Some residual DNAPL will be left in-situ, both inside and outside the focused treatment area, and will serve as a continuing source of dissolved-phase contamination to groundwater. Consequently, the required duration of long-term containment is not meaningfully reduced by this high cost source area RA (i.e., from 4,900 to 4,400 years). Additionally, contaminant mobilization in the short-term (if it were to occur) may result in lateral spreading or downward mobilization, thereby reducing the effectiveness of this RA in the long-term. The SVE component of this RA would reduce the VOC/DNAPL mass in the permeable unsaturated zone to a level that significantly reduces the future risk to the underlying groundwater from contaminant leaching. The permanence of the remedy is improved by removal of VOC/DNAPL mass from both the unsaturated and saturated zones, but ultimately, an insufficient amount of mass can be removed to significantly reduce the required duration of hydraulic containment in the long-term. ***Rank: Effective (but higher risks).***

Reduction of Toxicity, Mobility, and/or Volume of Hazardous Constituents. The SVE component of this RA would reduce the volume (and mass) and toxicity of hazardous constituents in the unsaturated zone. The mobility of DNAPL in the unsaturated zone would also be reduced by volatilization of the MCB component.

RA 6a reduces the volume and toxicity of DNAPL in the saturated zone within a focused treatment area where approximately 60% of the DNAPL mass at the Site is located (i.e., an estimated 473,700 pounds). ERH reduces the volume of DNAPL mass by heating the soils via electrical resistance and removing the MCB component of the DNAPL. Assuming that the MCB represents 50% of the DNAPL mass, an estimated 236,800 pounds of MCB is present in the focused treatment area and potentially subject to thermal remediation (although only a portion of this estimated mass would be recovered by ERH). Assuming that 80% of the MCB mass in the focused treatment area were removed by thermal remediation, an estimated 189,500 pounds of MCB would be removed. Some DNAPL will be left in place following ERH but is expected to be at residual levels. An estimated 284,200 pounds of MCB and DDT (primarily DDT) will be left within the focused treatment area following ERH. Residual MCB will serve as a continuing source of groundwater contamination but will be reduced in the long-term by dissolution and the hydraulic containment component of the RA.

The co-boiling point of the Montrose DNAPL at the base of the UBA (approximately 112 to 116°C) will slightly exceed the melting point of DDT (108.5°C at 1 atmosphere). As a result, liquid-phase DDT may be mobilized laterally or vertically downward by ERH. Some MCB may also remain in solution with the liquid-phase DDT and be carried with it. Once the liquid-phase DDT cools to temperatures below the melting point, it would precipitate as a solid and be relatively immobile in the environment. However, mobilization of the DDT in the subsurface at temperatures above the melting point is a possibility during ERH, which is contrary to the RAOs.

The ability of ERH to reduce the volume of DNAPL at the Site has not been pilot tested and is uncertain (i.e., Montrose DNAPL is unique and untested). The co-boiling point of the Montrose DNAPL (96°C) is relatively high in comparison with other VOCs and approaches the boiling point of water (100°C). A subsurface temperature of 96°C would be required to initiate co-boiling in the subsurface (at atmospheric pressure) and would need to be maintained for a sufficiently long period of time as to reduce the volume of MCB. However, if heating is not uniform in the subsurface, soil temperatures between electrodes may not reach 96°C. Additionally, soil temperatures near the electrodes may exceed 100°C before the mid-point between electrodes reaches 96°C. Under those circumstances, the groundwater around the electrode will begin to boil, increasing the resistivity of the soils and reducing electrical flow. If groundwater boils out of the soil at the electrodes before the mid-point between the electrodes reaches 96°C, ERH may not reduce DNAPL mass (and MCB volume) as significantly as at some other DNAPL-impacted sites. By comparison, TCE co-boils at a temperature of only 73°C. The lower the co-boiling point relative to the boiling point of water, the greater the potential for ERH to be effective in reducing DNAPL mass and MCB volume.

As identified in Section 5.2.4, other factors can inhibit the effectiveness of ERH in reducing DNAPL mass/volume. Water influx from outside the focused treatment area may inhibit the effectiveness of ERH in reaching target temperatures, particularly along the upgradient perimeter of the focused treatment area. Additionally, the target treatment interval of 45 feet is thicker than typically implemented for ERH, increasing the potential for non-uniform or inadequate heating (particularly at depth) and thus, less than optimal mass removal. Achieving target temperatures at depth within the saturated zone has proven to be problematic at several ERH case sites. For example, ERH was attempted to 105 feet bgs at the Paducah Gaseous Diffusion Plant in Kentucky but was unsuccessful in reaching target temperatures at the base of the treatment interval. Soil temperatures of only 30°C to 70°C were achieved between 95 and 105 feet bgs at the Paducah Site because the thick treatment interval resulted in poor performance of the deep electrodes (excessive length of the electrodes and weight of the steel shot backfill). Since heating to 105 feet bgs would also be required at the Montrose Site, achieving target temperatures at the bottom of the UBA may be problematic. ERH has not been implemented at depth (i.e., thick saturated zones) at sites that are comparable to Montrose. Although ERH was implemented to a depth of 95 feet bgs at the Pemaco Superfund Site (CH2M Hill, 2007), this site is not comparable to the Montrose Site for reasons identified in Sections 5.2.7 and Appendix L.

Even at sites where considerable effort has gone into thermal pilot testing, extensive computer modeling, design work, and technical review, there remains considerable uncertainty regarding performance of thermal remedies. For example, it has taken nearly 6 years for the full-scale ERH remedy to be implemented at the Paducah Gaseous Diffusion Plant following pilot testing in 2003, and yet there is considerable uncertainty regarding the effectiveness of heating the deeper portions of the Regional Gravel

Aquifer where a significant fraction of the TCE DNAPL is present. ***Rank: Reduces Toxicity, Mobility, and Volume (mobility increased in short-term).***

Short-Term Effectiveness. Although RA 6a may be effective in protecting human health and the environment in the short-term, there is an increased risk associated with excursions or upset conditions. Under this RA, the MCB component of the DNAPL is volatilized and extracted for ex-situ treatment. With thermal remediation projects, there is an increased potential for accidental release of heated vapors or contaminated steam to atmosphere as a fugitive emission. The higher temperatures and pressures associated with this RA can result in aboveground piping failure or accelerated corrosion. Additionally, the subsurface will remain hot even if remediation system operations are interrupted, and VOC vapors would continue to be generated in-situ even when the remediation system is not operating. Long periods of system downtime, without adequate soil vapor recovery, have the potential to cause VOC migration in the unsaturated zone.

The heated vapors must be effectively recovered in order to prevent contaminant migration in the subsurface. Although the layered and heterogeneous nature of the saturated UBA may not inhibit heating of the subsurface, it may reduce the effectiveness of recovering MCB volatilized by ERH. Unrecovered MCB vapors will re-condense in cooler portions of the surbsurface, potentially located outside the footprint of the focused treatment area. Migration of MCB vapors underneath the adjacent commercial building located at the former Boeing Realty Corporation property would reduce the protectiveness of this RA in the short-term. The high density of ERH wells (relative to steam injection) reduces the risk associated with vapor migration and contaminant recovery. However, the high density of ERH wells (182 total electrode locations, multiphase, and temperature monitoring wells) also increases the risk of downward migration to occur as a result of drilling activities. Each well drilled through the DNAPL-impacted soils to the very base of the UBA creates a vertical conduit with the potential for downward DNAPL migration in the short-term.

The short-term effectiveness of the ex-situ vapor treatment system and SVE component of this RA would be similar to RA 3. However, due to the increased VOC mass removal, disposable carbon/resin would no longer be the most cost-effective. One of the other two ex-situ vapor treatment technologies would be used for this RA, and steam-regenerable carbon/resin is assumed for purposes of estimating cost and remedy evaluation in this FS. Spent carbon would be regenerated on-Site using low pressure steam, cooled using air, and placed back into service. The steam and recovered VOCs would be condensed and separated. The recovered VOCs (DNAPL) would be temporarily accumulated on-Site pending disposal within 90 days of generation. The condensed steam would be combined with extracted groundwater and treated on-Site using carbon and advanced oxidation (i.e., HiPOx). The steam-regenerable carbon/resin would be effective in protecting human health and the environment in the short-term, but it is a more complex system requiring an increased level of maintenance and oversight. Secondary containment would be required for the system to prevent accidental releases of steam condensate or DNAPL to the ground surface or stormwater pathways. Engineering controls would be required to automatically terminate system operations upon exceedance of emissions limits to ensure compliance with air quality standards. The system would also be engineered to automatically terminate operations to prevent over-filling of the temporary accumulation tanks, and upon detection of leaks within the secondary containment.

However, RA 6a presents an increased potential for fugitive emissions during remedy implementation as compared with RAs 3 and 4. Heated vapors and some steam will be recovered during remedy implementation for ex-situ treatment. The potential for fugitive emissions increases as a result of handling heated vapors, either through accelerated corrosion or pipe fittings/threads. As previously indicated for RA 5a, the plastic piping materials used at the Silresim Superfund Site and Cape Fear Wood Preserving Site suffered a complete loss of mechanical integrity during ERH pilot testing, releasing heated vapors and steam to atmosphere. Similarly, heated vapors and steam can escape to surface through wells or previously abandoned borings that are not able to withstand the elevated temperatures associated with this RA, such as experienced at the SCE Visalia Site during the full-scale steam injection remedy. Routine inspection of the aboveground soil vapor piping and equipment would be required during remedy implementation to detect and subsequently correct any fugitive emissions of heated soil vapors or steam. Fugitive emissions, if any, during remedy implementation would reduce the protectiveness of this RA in the short-term. ***Rank: Potentially Effective (but higher risks).***

Implementability. As described in Section 5.2.8, RA 6a would be difficult to implement. A large number of electrodes (102) and multiphase extraction wells (66) would be required to treat the focused treatment area, including the isolated area surrounding boring SSB-12. This RA would also create a significant amount of waste requiring management and disposal. A large amount of electricity would be required to implement this RA (8,680 megawatt-hours), and a substantial amount of electrical equipment would require installation at the Site. Additionally, this RA would require implementation of SVE in the unsaturated zone, ex-situ vapor treatment, and ex-situ groundwater treatment. This RA would require skilled operators and a high level of maintenance. However, unlike steam injection, three qualified ERH vendors (TRS, CES, and MC2) are available to implement this RA, and ERH is much more frequently implemented than steam injection. ***Rank: Difficult To Implement.***

Cost. The estimated cost of RA 6a is $21.2 to $22.9 MM NPV as shown in Table 6.1 and Appendix J and is based on input and a preliminary estimate from McMillan-McGee, an ERH technology vendor. As described in Section 5.2.8, the cost of this RA includes 102 electrode locations and 66 multiphase extraction wells, including the isolated area surrounding SSB-12. The amount of energy consumed by the RA is very costly and was assumed to be 200 kW-hr per cubic yard based on a recommendation by McMillan-McGee. The cost of a higher energy demand scenario was estimated in the event that the assumed 200 kW-hr per cubic yard is insufficient to reach and maintain target temperatures. If an additional 35% energy demand is required (70 kW-hr per cubic yard), the incremental cost was estimated at $1.7 MM NPV, increasing the total cost of the RA to $22.9 MM NPV. Further, climate change regulation is expected to increase the costs of both natural gas and electricity because upstream suppliers of these commodities are expected to be regulated at both the State and Federal level. In other words, as a price is placed on carbon emissions, whether directly via a carbon tax or, more likely, indirectly via State and/or Federal cap-and-trade regimes, the cost of carbon-intensive forms of energy (e.g., natural gas and non-renewably generated electricity) will increase. Such increased costs would add additional cost to this RA.

ERH costs were previously estimated and submitted to EPA in November 2007 (Earth Tech, 2007f). Following cost reconciliation discussions in December 2007 and January 2008, ERH costs were revised and resubmitted to EPA in August 2008 (Earth Tech, 2008f). EPA did not comment on that estimate, but it included the cost of a hot floor underlying the UBA. As explained in Section 5.1.8, ERH presents a reduced potential for downward migration (as compared with steam injection), and implementation of a hot floor in the underlying BFS may not be required. Therefore, the cost of this RA has been revised to exclude the hot floor, but all other cost assumptions, unit costs, and quantities remain the same, as shown in Appendix J. Budgetary price quotations were obtained from subcontractors and equipment vendors to increase the relative accuracy and reliability of these remedy cost estimates.

The duration of the remedy is assumed to be 4 years total based on the following schedule of activities:

- Year 1 = Design
- Year 2 = Construction
- Year 3 = O&M (1 year)
- Year 4 = Verification and Abandonment

A duration of 1 year has been assumed for ERH within the focused treatment area based on cost reconciliation discussions with EPA. Soil vapors are assumed to be treated using steam-regenerable carbon instead of disposable carbon due to the increased mass removal. As a result, sorbed VOCs are recovered, cooled, and temporarily accumulated pending off-Site transport and disposal. DNAPL recovered from spent carbon would be disposed off-Site by incineration. Ex-situ treatment of groundwater is additionally included and reflects a combination of disposable carbon and advanced oxidation (i.e., HiPOx). The cost of the institutional controls component is identical to RA 2. However, the estimated ERH cost includes SVE within the unsaturated UBA (45 to 60 feet bgs), and thus the SVE component was reduced to reflect only SVE within the PVS from approximately 25 to 45 feet bgs.

In comparison, the cost of long-term hydraulic containment is estimated at $1.1 MM NPV as indicated in Section 6.2.5. Assuming a discount rate of 4%, it is noted that costs incurred after approximately Year 350 do not contribute at all (not even $1) to the NPV total. As a result, there is no difference in the NPV cost of long-term hydraulic containment between estimated timeframes of 4,400, 4,600, or 4,900 years. The cost of source depletion under RA 6a ($21.2 to $22.9 MM NPV) is significantly higher than the cost of long-term hydraulic containment ($1.1 MM NPV). In accordance with the decision criteria established by an EPA-sponsored expert panel in 2003 (*The DNAPL Remediation Challenge: Is There a Case for Source Depletion*; EPA, 2003), source depletion may not be necessary at the Montrose Site. There is little cost benefit of implementing a $21.2 to $22.9 MM NPV source zone depletion remedy if long-term hydraulic containment will still be required for an estimated 4,400 years. Overall, RA 6a is a high cost remedy and is not cost-effective because it does not meaningfully reduce hydraulic containment timeframes. ***Rank: High Cost ($21.2 to $22.9 MM NPV).***

State Acceptance. This criterion will be discussed in more detail once comments on the Final DNAPL FS are received from the State. EPA will address this criterion in the ROD. However, the relatively high GHG emissions associated with this RA may not be favorable to the State. ***Rank: Not Applicable.***

Public Acceptance. Because ERH is a thermal remedy, public acceptance for RA 6a may be lower than that for some the non-thermal RAs under consideration. ERH implemented within the focused treatment area would generate heated soil vapors, which would be extracted for ex-situ treatment. Thermal remediation projects present an increased potential for heated vapors or contaminated steam to be accidentally released to atmosphere as fugitive emissions. Additionally, long periods of system downtime, without adequate soil vapor recovery, have the potential to cause VOC migration in the unsaturated zone. VOCs not effectively recovered during implementation of this RA will re-condense in cool areas of the Site, potentially outside of the treatment area footprint. Following treatment, the subsurface may remain hot for years, posing a VOC migration risk far beyond the duration of the thermal remedy.

This RA would additionally require ex-situ treatment of soil vapors at a flow rate approximately twice that required for RAs 3 and 4. Due to the increased VOC mass removal under this RA, disposable carbon/resin would no longer be the most cost-effective ex-situ vapor treatment technology. Instead, one of the other two vapor treatment technologies, which may be less acceptable to the public, would be required under this RA. This RA additionally requires ex-situ treatment of groundwater, adding to the infrastructure and complexity of the remedy, which would be re-injected off-Property into the BFS and Gage Aquifer instead of the UBA. Although this RA would use less energy than RA 5a, it would use significantly more energy and generate more greenhouse gas emissions than RA 4. As previously discussed, high energy demand and greenhouse gas emissions have historically been significant public concerns. Despite the high carbon footprint and high remedy costs, this RA would leave a significant amount of contaminant mass both within the focused treatment area (284,200 pounds; primarily DDT). Preferential removal of the MCB component of the DNAPL, leaving the DDT component behind, may not be acceptable to the public.

The public acceptance of the institutional control component of this RA would be the same as for RA 2. Institutional controls restricting Site use and activities, with the potential for exposure to DNAPL-impacted soils, are expected to be acceptable to the public. ***Rank: May Not Be Accepted.***

6.3 SUMMARY OF REMEDIAL ALTERNATIVES DETAILED ANALYSIS

A comparative analysis of the six RAs is provided in Section 7. The relative performance of the RAs under each of the nine NCP criteria is discussed and ranked. As way of review, a summary of results from the Section 6 detailed analysis is provided below:

DETAILED EVALUATION OF CANDIDATE RAs

NCP Criterion	RA 1	RA 2	RA 3	RA 4	RA 5a	RA 6a
Protection of Human Health and Environment	Yes but no ICs	Yes	Yes	Yes	Yes But has risks	Yes But has risks
Compliance with ARARs	No	Yes	Yes	Yes	Yes (except for global warming)	Yes(except for global warming)
Carbon Footprint, lbs GHG →	(0 MM)	(0 MM)	(2.2 MM)	(4.2 MM)	(46 MM)	(14 MM)
Trees required to offset GHG →	(0 trees)	(0 trees)	(14,200 trees)	(27,300 trees)	(297,400 trees)	(88,500 trees)
Long-Term Effectiveness	Effective	Effective	Effective	Effective	Effective But has risks	Effective But has risks
Containment Timeframe→	4,900 years	4,900 years	4,900 years	4,600-4,700 years	4,300-4,500 years	4,300-4,500 years
Reduction of Toxicity, Mobility, or Volume (in short-term)						
Unsaturated Zone MCB Mass Reduction[c] →	0 lbs	0 lbs	248,000 lbs	248,000 lbs	248,000 lbs	248,000 lbs
Saturated UBA MCB Mass Reduction[d] →	0 lbs	0 lbs	0 lbs	88,700 lbs	189,500 lbs	189,500 lbs
Total MCB Mass Reduction →	**0 lbs**	**0 lbs**	**248,000 lbs**	**336,700 lbs**	**437,500 lbs**	**437,500 lbs**
Saturated UBA DDT Mass Reduction[d] →	0 lbs	0 lbs	0 lbs	88,700 lbs	>0 lbs[a]	0 lbs
Total MCB+DDT Mass Reduction →	**0 lbs**	**0 lbs**	**248,000 lbs**	**425,400 lbs**	**>437,500 lbs[a]**	**437,500 lbs**
Mobile MCB+DDT Mass Removal→	**0 lbs**	**0 lbs**	**0 lbs**	**177,400 lbs**	**<110,900 lbs[b]**	**<110,900 lbs[b]**
Short-Term Effectiveness	Effective	Effective	Effective	Effective	Potentially Effective	Potentially Effective
Implementability	Implementable	Implementable	Implementable	Implementable	Difficult to implement	Difficult to implement
Cost (MM NPV)	$1.1	$1.3	$5.9	$11.7	$24.6-$25.8	$21.2-$22.9
Unit Cost ($/lb removed) →	NA	NA	$19/lb	$33-$40/lb	$110-$116/lb	$92-$101/lb
State Acceptance	NA	NA	NA	NA	NA	NA
Public Acceptance	May Accept	May Accept	May Accept	May Accept	May Not Accept	May Not Accept

Notes:

ICs = Institutional Controls
SVE = Soil Vapor Extraction
SF = Steam Flushing
MM = million
HC = Hydraulic Containment
HD = Hydraulic Displacement
ERH = Electrical Resistance Heating
GHG = Greenhouse Gases
NA = Not Applicable
NPV = Net Present Value
Lbs = pounds
[d]80% mass removal assumed for HD (mobile only), steam, and ERH
[a]Some DNAPL-phase DDT will be removed by RA 5a
[b]Will not remove >100% of mobile MCB mass
[c]95% MCB mass removal assumed for SVE

TABLES

Table 6.1
Detailed Evaluation of DNAPL Remedial Alternatives
Montrose Superfund Site

Remedial Alternative Description	Overall Protection of Human Health	Compliance with ARARs	Long-Term Effectiveness And Permanence	Reduction of Toxicity, Mobility, and/or Volume	Short-Term Effectiveness	Implementability	Cost	State Acceptance	Public Acceptance
RA 1 • No Action • Hydraulic Containment	**Moderately Protective** • Soil remedy will limit exposure at surface • Groundwater remedy will limit exposure to dissolved-phase contaminants • DNAPL occurs fully within TI Waiver Zone • No risk of DNAPL migration outside of TI Waiver Zone	**Does Not Comply** • Not in compliance with Land Use Covenant requirements • Deed restrictions may be required to prevent exposure to DNAPL-impacted soils	**Moderately Effective** • Meets RAOs in the long-term via dissolution and HC • HC timeframe estimated at 4,900 years	**Reduces Toxicity, Mobility, and Volume** • HC reduces DNAPL mass in the saturated zone in the long-term • No reduction in the short-term • No active MCB mass reduction in unsaturated zone	**Effective**	**Implementable**	**Cost = $1.1 MM NPV** • Cost includes HC after Year 50 of the remedy for groundwater • Average extraction rate of 225 gpm from 7 wells • Ex-situ treatment and re-injection into 2 Gage wells • Includes routine well rehabilitation and pump/controls replacement • Includes replacement of major equipment every 20 years • Costs incurred after Year 350 do not contribute (even $1) to NPV total	**Not Applicable**	**May Be Accepted** • No ex-situ soil vapor, groundwater, or DNAPL treatment systems • No potential for release of contaminants to air or ground surface • No greenhouse gas emissions • Does not contribute to global warming
RA 2 • Hydraulic Containment • ICs	**Protective** • ICs protect human health by restricting Site access, use, and controlling exposure pathways • Nearly all of the DNAPL occurs at the Montrose Property where land use can be effectively controlled	**Complies** • Complies with Land Use Covenant requirements	**Moderately Effective** • Meets RAOs in the long-term via dissolution and HC • HC timeframe estimated at 4,900 years	**Reduces Toxicity, Mobility, and Volume** • HC reduces DNAPL mass in the saturated zone in the long-term • No reduction in the short-term • No active MCB mass reduction in unsaturated zone	**Effective**	**Implementable** • A small amount of DNAPL may occur at the former Boeing Realty Corp property to the north • Compliance with land use ARARs would require consent by the land owner	**Cost = $1.3 MM NPV** • Includes $1.1 MM NPV for HC • Cost includes establishing Land Use Covenant at Montrose Property and annual site inspections for 30 years • Potential costs associated with land use restrictions in off-Property areas are uncertain and assigned a minimal cost	**Not Applicable**	**May Be Accepted** • No ex-situ soil vapor, groundwater, or DNAPL treatment systems • No potential for release of contaminants to air or ground surface • No greenhouse gas emissions • Does not contribute to global warming
RA 3 • Hydraulic Containment • ICs • SVE in unsaturated zone (25-60 feet bgs)	**Protective** • ICs protect human health by restricting Site access, use, and controlling exposure pathways • Nearly all of the DNAPL occurs at the Montrose Property where land use can be effectively controlled • Future risk to groundwater is reduced by SVE and removal of MCB mass from permeable unsaturated zone • Does not significantly contribute to global warming; low GHG emissions	**Complies** • Complies with Land Use Covenant requirements • SVE system would need to comply with air emission ARARs • All three ex-situ vapor treatment technologies capable of meeting ARARs (disposable GAC, steam regenerable GAC, thermal oxidation) • Small carbon footprint generating an estimated 2.2 MM lbs GHG • 14,200 trees required to offset GHG	**Effective** • Meets RAOs in the long-term via dissolution and HC • MCB mass in the unsaturated zone is permanently reduced by SVE in the short-term • HC timeframe estimated at 4,900 years	**Reduces Toxicity, Mobility, and Volume** • HC reduces DNAPL mass in the saturated zone in the long-term • No short-term reduction of MCB mass in saturated zone • An estimated 248,000 lbs MCB reduced in unsaturated zone assuming 95% mass removal efficiency • Residual DDT in the unsaturated zone will sorb strongly to soils and be relatively immobile in environment	**Effective** • Disposable GAC is lowest cost ex-situ vapor treatment technology that complies with ARARs • High MCB adsorption rate in GAC demonstrated during SVE pilot testing • Spent GAC is disposed/recycled off-Site; no on-Site regeneration of GAC or temporary storage of liquid-phase MCB • Does not involve any combustion processes; no potential for formation of dioxins/furans	**Implementable** • SVE is a widely used technology for removing VOCs from permeable unsaturated soils • Equipment and contractors are readily available • Highly skilled operators are not required for ex-situ treatment using disposable GAC	**Cost = $5.9 MM NPV** • Includes $1.3 MM NPV for HC and ICs • 23 SVE wells screened in either the PVS (25-45 feet bgs) or unsaturated UBA (45-60 feet bgs) • 1,500 scfm SVE system • Ex-situ treatment using GAC; lowest cost treatment technology that complies with air emission ARARs • GAC adsorption capacity of 25% MCB by weight • 4 years O&M	**Not Applicable**	**May Be Accepted** • Protective in short and long-term • Low risk • No thermal oxidation, combustion process, or potential for formation of dioxins/furans • No on-Site regeneration of spent GAC • No ex-situ groundwater treatment • No temporary DNAPL storage • Low energy consumption and GHG emissions

Table 6.1
Detailed Evaluation of DNAPL Remedial Alternatives
Montrose Superfund Site

Remedial Alternative Description	Overall Protection of Human Health	Compliance with ARARs	Long-Term Effectiveness And Permanence	Reduction of Toxicity, Mobility, and/or Volume	Short-Term Effectiveness	Implementability	Cost	State Acceptance	Public Acceptance
RA 4 • Hydraulic Containment • ICs • SVE in unsaturated zone (25-60 feet bgs) • HD in saturated zone, with untreated water re-injection	**Protective** • ICs protect human health by restricting Site access, use, and controlling exposure pathways • Nearly all of the DNAPL occurs at the Montrose Property where land use can be effectively controlled • Future risk to groundwater is reduced by SVE and removal of MCB mass from permeable unsaturated zone • Does not significantly contribute to global warming; low GHG emissions • DNAPL mass and mobility are reduced, in turn reducing the future risk of DNAPL migration • Computer modeling predicts that DNAPL will not be mobilized past basal silty sand by HD • Computer modeling predicts that proposed well densities will be effective in mobilizing DNAPL for recovery	**Complies** • Complies with Land Use Covenant requirements • SVE system would need to comply with air emission ARARs • Temporary on-Site storage of DNAPL would need to meet hazardous material storage regulations • In-situ groundwater standards would need to be waived in order to re-inject untreated groundwater, as they were for 2004/2005 pilot test • Relatively small carbon footprint generating an estimated 4.2 MM lbs GHG • 27,300 trees required to offset GHG	**Effective** • Meets RAOs in the long-term via dissolution and HC • MCB mass in the unsaturated zone is permanently reduced by SVE in the short-term • Mobile DNAPL mass in the saturated zone is permanently reduced by HD in the short-term • HC timeframe estimated at 4,600-4,700 years • Insufficient DNAPL mass can be removed to meaningfully reduce HC timeframe	**Reduces Toxicity, Mobility, and Volume** • HC reduces DNAPL mass in the saturated zone in the long-term • An estimated 248,000 lbs MCB reduced in unsaturated zone assuming 95% mass removal efficiency • An estimated 88,700 lbs MCB or 177,400 lbs of mobile DNAPL (MCB+DDT) reduced in saturated zone assuming 80% mobile mass removal efficiency • Higher capillary pressures are required to mobilize DNAPL at saturations approaching residual, so mass removal efficiencies approaching 100% are unlikely • Field pilot testing has demonstrated effectiveness of HD throughout mobile DNAPL footprint, without benefit of water re-injection to enhance hydraulic gradients • Up to 5.6 gallons per day of DNAPL recovered from a single well • Computer modeling predicts that HD will effectively mobilize DNAPL for recovery at proposed well spacing (25-50 feet)	**Effective** • Disposable GAC is lowest cost ex-situ vapor treatment technology that complies with ARARs • High MCB adsorption rate in GAC demonstrated during SVE pilot testing • Spent GAC is disposed/recycled off-Site; no on-Site regeneration of GAC • Does not involve any combustion processes; no potential for formation of dioxins/furans • Temporary on-Site storage of DNAPL is required; engineering controls effective in protecting human health • No ex-situ groundwater treatment required, other than DNAPL separation and filtration	**Implementable** • SVE is a widely used technology for removing VOCs from permeable unsaturated soils • Standard separation techniques are effective for DNAPL/groundwater • Equipment and contractors are readily available • SVE with disposable GAC and HD with untreated water re-injection do not require highly skilled operators • Low to moderate level of maintenance required for this RA	**Cost = $11.7 MM NPV** • Includes $5.9 MM NPV for HC, ICs, and SVE • Includes 18 extraction and 23 injection wells on 50-foot spacing • Cost increases to $13.0 MM NPV for wells on 25-foot spacing • 5 years O&M • Re-injection of untreated groundwater; includes DNAPL separation and groundwater filtration • Off-Site disposal of recovered DNAPL via incineration	**Not Applicable**	**May Be Accepted** • Protective in short and long-term • Low risk • No thermal oxidation, combustion process, or potential for formation of dioxins/furans • No on-Site regeneration of spent GAC • All groundwater is re-injected into UBA at the Property; no off-Property injection of groundwater • Reduced amount of infrastructure relative to RAs 5a and 6a • Relatively low energy consumption and GHG emissions

Table 6.1
Detailed Evaluation of DNAPL Remedial Alternatives
Montrose Superfund Site

Remedial Alternative Description	Overall Protection of Human Health	Compliance with ARARs	Long-Term Effectiveness And Permanence	Reduction of Toxicity, Mobility, and/or Volume	Short-Term Effectiveness	Implementability	Cost	State Acceptance	Public Acceptance
RA 5a • Hydraulic Containment • ICs • SVE in unsaturated zone (25-60 feet bgs) • Steam injection in saturated zone, over focused treatment area, with hot floor	**Protective (higher risks)** • ICs protect human health by restricting Site access, use, and controlling exposure pathways • Future risk to groundwater is reduced by SVE and removal of MCB mass from permeable unsaturated zone • Removes DNAPL mass (primarily MCB) from focused treatment area where majority of DNAPL occurs (and all mobile DNAPL) • Increased risk of contamination migration • Risk of lateral spreading including under building at adjacent former Boeing Realty Corp property • EPA proposed well spacing (60 feet) larging than spacing considered for HD or ERH • DNAPL mobility increased at steam front, resulting in increased risk of downward migration • Condensed steam would become contaminated upon contact with DNAPL and may result in downward migration • Hot floor included in RA, but potential effectiveness uncertain; not demonstrated at comparable site • High GHG emissions contributes to global warming	**Complies (except for global warming TBCs)** • Complies with Land Use Covenant requirements • SVE system and steam boiler would need to comply with air emission ARARs • Temporary on-Site storage of DNAPL would need to meet hazardous material storage regulations • Additional waste generation required by this RA including boiler brine waste; must comply with waste management regulations • Re-injection of treated groundwater off-Property into the BFS and Gage would comply with in-situ groundwater standards • Increased risk of excursions and fugitive emissions, which would not comply with ARARs • Large carbon footprint generating an estimated 46 MM lbs GHG • 297,400 trees required to offset GHG • Does not comply with global warming TBCs	**Effective (higher risks)** • Meets RAOs in the long-term via dissolution and HC • MCB mass in the unsaturated zone is permanently reduced by SVE in the short-term • DNAPL mass in the saturated zone is permanently reduced by steam injection over a focused treatment area in the short-term • Some DNAPL will be left in-situ both inside and outside the focused treatment area • HC timeframe estimated at 4,300-4,500 years • Insufficient DNAPL mass can be removed to meaningfully reduce HC timeframe	**Reduces Toxicity, Mobility, and Volume** • HC reduces DNAPL mass in the saturated zone in the long-term • An estimated 248,000 lbs MCB reduced in unsaturated zone assuming 95% mass removal efficiency • An estimated 189,500 lbs MCB reduced in saturated zone assuming 80% mass removal efficiency • Given characteristics of Site, removal of even 80% of the MCB mass is considered optimistic • Some liquid-phase DNAPL may be displaced at steam front • Mobility of DNAPL is increased in the short-term • Steam injection has not been field pilot tested, and performance is highly uncertain • Steam will preferentially flow through higher permeability sand layers; heating of lower permeability layers may be problematic • Groundwater influx may cool the upgradient perimeter of the focused treatment area, reducing effectiveness • Steam has never been applied to a DNAPL site where either MCB or DDT was a primary component • Potential to mobilize liquid-phase DDT at temperatures above the melting point (108.5°C at 1 atmosphere) • Co-boiling point of DNAPL (96°C) is relatively high compared with other VOCs • Lithology at thermal sites (e.g., sand aquifers) is better suited to steam injection than heterogeneous UBA • EPA proposed only 2 to 3 pore volumes steam flushing; lower energy and steam delivery may result in reduced MCB mass removal	**Potentially Effective** • Greatest potential for remedy excursions or upset conditions • Displaced DNAPL, contaminated steam condensate, and heated MCB vapors must be effectively recovered to prevent contaminant migration • Lateral spreading under building at adjacent former Boeing Realty Corp property would reduce protectiveness • Steam injection well density lower than other RAs; greatest risk of not recovering all mobilized contaminants • Risk of downward migration resulting from installation of 36 hot floor wells through DNAPL-impacted UBA to underlying BFS • Spent GAC would be steam regenerated on-Site for re-use • Temporary on-Site storage of DNAPL from regenerable GAC system would be required • More complex ex-situ equipment requiring an increased level of maintenance and oversight • Increased potential for fugitive emissions through pipe fittings/threads, accelerated corrosion, or through well construction materials not compatible with elevated temperatures and pressures • Steam boiler will also emit nitrogen and sulfur oxides	**Difficult to Implement** • SVE is a widely used technology for removing VOCs from permeable unsaturated soils • A significant amount of infrastructure would be required • Ex-situ treatment of groundwater is required prior to re-injection off-Property into the BFS and Gage; flow requirement would need to be considered during design of Groundwater Remedy Treatment System • Hot floors are infrequently implemented at thermal remediation sites • Highly skilled operators are required • High level of maintenance is required, including boiler maintenance, water conditioning, and brine disposal • Steam injection is not implemented as frequently as ERH or ISTD; ERH and ISTD not as dependent on permeability and do not present the same mobilization risks as steam injection; heating is more controlled under ERH and ISTD and less prone to displacement or uncontrolled steam flow • Only four active steam injection sites in US • Some vendors have abandoned steam injection as a commercial technology; only two vendors remain (TerraTherm and Praxis); only one of which has the resources to implement a project of this size	**Cost = $24.6 to $25.8 MM NPV** • Includes $3.8 MM NPV for HC, ICs, and SVE in PVS (25-45 feet); SVE in UBA (45-60 feet) is included as part of steam injection remedy costs • Includes 14 steam injection, 27 multiphase extraction, and 14 temperature monitoring points on 60-foot spacing • 1 year steam injection in UBA (13 months in hot floor) • Energy demand reduced to between 2 and 3 pore volumes steam flushing in UBA based on EPA comments regarding energy balance • Includes hot floor in BFS underlying focused treatment area • Includes ex-situ soil vapor treatment using steam regenerable GAC system (with polishing GAC for air emissions compliance) • Includes ex-situ groundwater/condensate treatment using disposable GAC and HiPOx • Off-Site disposal of recovered DNAPL via incineration	**Not Applicable**	**May Not Be Accepted** • This RA includes the greatest amount of infrastructure, complexity, uncertainty, and mobilization risk • Potentially the least acceptable RA to the public • Highest energy demand and carbon footprint, emitting the most GHG • Increased potential for fugitive emissions • Subsurface will remain hot, even when system is off, and continue to generate MCB vapors in-situ; VOC migration may occur during long periods of system downtime • Subsurface will remain hot, potentially for years, following the duration of the thermal remedy; posing a VOC migration risk far beyond the duration of the thermal remedy • Increased risk of lateral spreading and downward migration • Soil vapor flow rate will be approximately twice that of RAs 3 and 4 • Use of disposable GAC no longer cost effective • Spent GAC would be re-generated on-Site using steam; may be less acceptable to public

Table 6.1
Detailed Evaluation of DNAPL Remedial Alternatives
Montrose Superfund Site

Remedial Alternative Description	Overall Protection of Human Health	Compliance with ARARs	Long-Term Effectiveness And Permanence	Reduction of Toxicity, Mobility, and/or Volume	Short-Term Effectiveness	Implementability	Cost	State Acceptance	Public Acceptance
RA 6a • Hydraulic Containment • ICs • SVE in unsaturated zone (25-60 feet bgs) • ERH in saturated zone, over focused treatment area, no hot floor	**Protective (higher risks)** • ICs protect human health by restricting Site access, use, and controlling exposure pathways • Future risk to groundwater is reduced by SVE and removal of MCB mass from permeable unsaturated zone • Removes DNAPL mass (primarily MCB) from focused treatment area where majority of DNAPL occurs (and all mobile DNAPL) • Increased risk of contamination migration, such as not recovering all heated vapors • Risk of lateral spreading of vapor-phase contaminants including under building at adjacent former Boeing Realty Corp property • Unrecovered vapors may migrate to cooler areas and re-condense, including outside the remediation footprint • However, risks are reduced by higher density of wells, as compared with RA 5a • High GHG emissions contributes to global warming	**Complies (except for global warming TBCs)** • Complies with Land Use Covenant requirements • SVE system would need to comply with air emission ARARs • Temporary on-Site storage of DNAPL would need to meet hazardous material storage regulations • Additional waste generation required by high well density; must comply with waste management regulations • Re-injection of treated groundwater off-Property into the BFS and Gage would comply with in-situ groundwater standards • Increased risk of excursions and fugitive emissions, which would not comply with ARARs • Large carbon footprint generating an estimated 14 MM lbs GHG • 88,500 trees required to offset GHG • Does not comply with global warming TBCs	**Effective (higher risks)** • Meets RAOs in the long-term via dissolution and HC • MCB mass in the unsaturated zone is permanently reduced by SVE in the short-term • DNAPL mass in the saturated zone is permanently reduced by ERH over a focused treatment area in the short-term • Some DNAPL will be left in-situ both inside and outside the focused treatment area • HC timeframe estimated at 4,300-4,500 years • Insufficient DNAPL mass can be removed to meaningfully reduce HC timeframe	**Reduces Toxicity, Mobility, and Volume** • HC reduces DNAPL mass in the saturated zone in the long-term • An estimated 248,000 lbs MCB reduced in unsaturated zone assuming 95% mass removal efficiency • An estimated 189,500 lbs MCB reduced in saturated zone assuming 80% mass removal efficiency • Given characteristics of Site, removal of even 80% of the MCB mass is considered optimistic • Mobility of DNAPL is increased in the short-term • ERH has not been field pilot tested, and performance is highly uncertain • Groundwater influx may cool the upgradient perimeter of the focused treatment area, reducing effectiveness • ERH has never been applied to a DNAPL site where either MCB or DDT was a primary component • Co-boiling point of DNAPL (96°C) is relatively high compared with other VOCs and approaches the boiling point of water (100°C) • Narrow gap between MCB co-boiling point and water boiling point increases the potential for desaturation, reduced electrical current flow, and non-uniform heating • Thick saturated interval of 45 feet has not been implemented at a comparable site; heating at the base of the thick saturated interval may be problematic	**Potentially Effective** • Increased potential for remedy excursions or upset conditions • Heated MCB vapors must be effectively recovered to prevent contaminant migration; heterogeneous and highly layered UBA may inhibit effective recovery of MCB vapors • Lateral spreading under building at adjacent former Boeing Realty Corp property would reduce protectiveness • High density of wells reduces risk of lateral spreading to some degree • Increased risk of downward migration resulting from installation of 182 total ERH electrodes, wells, and monitoring points through the DNAPL-impacted UBA • Spent GAC would be steam regenerated on-Site for re-use • Temporary on-Site storage of DNAPL from regenerable GAC system would be required • Complex ex-situ equipment requiring an increased level of maintenance and oversight • Increased potential for fugitive emissions through pipe fittings/threads, accelerated corrosion, or through well construction materials not compatible with elevated temperatures	**Difficult to Implement** • SVE is a widely used technology for removing VOCs from permeable unsaturated soils • A significant amount of infrastructure and a large amount of electricity would be required • Ex-situ treatment of groundwater is required prior to re-injection off-Property into the BFS and Gage; flow requirement would need to be considered during design of Groundwater Remedy Treatment System • Highly skilled operators are required • High level of maintenance is required • Three qualified ERH vendors are available to implement (TRS, CES, and McMillan-McGee) • ERH is implemented far more frequently than steam injection	**Cost = $21.2 to $22.9 MM NPV** • Includes $3.8 MM NPV for HC, ICs, and SVE in PVS (25-45 feet); SVE in UBA (45-60 feet) is included as part of ERH remedy costs • Includes 102 electrode locations, 66 multiphase extraction, and 14 temperature monitoring points on 21-foot spacing • 1 year ERH in UBA • Energy demand reflects 200 to 270 kw-hrs per cubic yard • Includes ex-situ soil vapor treatment using steam regenerable GAC system (with polishing GAC for air emissions compliance) • Includes ex-situ groundwater/condensate treatment using disposable GAC and HiPOx • Off-Site disposal of recovered DNAPL via incineration	**Not Applicable**	**May Not Be Accepted** • This RA includes the large amount of infrastructure, complexity, uncertainty, and mobilization risk • Potentially not acceptable RA to the public • Second highest energy demand and carbon footprint, emitting significant GHG • Increased potential for fugitive emissions • Subsurface will remain hot, even when system is off, and continue to generate MCB vapors in-situ; VOC migration may occur during long periods of system downtime • Subsurface will remain hot, potentially for years, following the duration of the thermal remedy; posing a VOC migration risk far beyond the duration of the thermal remedy • Increased risk of vapor-phase contaminant migration • Soil vapor flow rate will be approximately twice that of RAs 3 and 4 • Use of disposable GAC no longer cost effective • Spent GAC would be re-generated on-Site using steam; may be less acceptable to public

Notes:
ICs = institutional controls
HC = hydraulic containment
HD = hydraulic displacement
ERH = electrical resistance heating
bgs = below ground surface
lbs = pounds
MM = million
GHG = greenhouse gases
MCB = monochlorobenzene
GAC = granular activated carbon
NPV = net present value
VOCs = volatile organic compounds
SVE = soil vapor extraction
O&M = operations and maintenance
PVS = Palos Verdes Sand
UBA = Upper Bellflower Aquitard
BFS = Bellflower Sand
RAOs = remedial action objectives
RA = remedial alternative
ISTD = in-situ thermal destruction
kw-hrs = kilowatt-hours

Section 7.0

Comparative Analysis of Remedial Alternatives

7.0 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents a comparative analysis of the six RAs evaluated in Section 6. The candidate DNAPL RAs evaluated in Section 6 are summarized as follows:

Candidate DNAPL RAs

RA	Remedy Components
RA 1	No Action Hydraulic Containment
RA 2	Hydraulic Containment Institutional Controls
RA 3	Hydraulic Containment Institutional Controls SVE in Unsaturated Zone
RA 4	Hydraulic Containment Institutional Controls SVE in Unsaturated Zone Hydraulic Displacement
RA 5a	Hydraulic Containment Institutional Controls SVE in Unsaturated Zone Steam Injection, Focused Treatment Area with Hot Floor
RA 6a	Hydraulic Containment Institutional Controls SVE in Unsaturated Zone ERH, Focused Treatment Area without Hot Floor

In Section 6, the six candidate DNAPL RAs were evaluated against nine performance criteria defined by the NCP. In this section, the performance of those RAs is compared collectively against each criterion. A list of the nine performance criteria is provided below, and the following sections present the comparative analysis by criterion. A description of these criteria has been provided in Section 6.0.

<u>Threshold Criteria</u>

- Overall protection of human health and the environment
- Compliance with ARARs

<u>Balancing Criteria</u>

- Long-term effectiveness and permanence

- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

Modifying Criteria

- State acceptance
- Public acceptance

A summary of the comparative analysis is provided in Section 7.10, along with presentation of the Montrose preferred RA. However, EPA will identify a recommended DNAPL remedy in the Proposed Plan following review and approval of this FS.

7.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

All six of the RAs are considered either moderately protective or protective of human health and the environment as follows:

Protection of Human Health and the Environment Ranking

RA	Components	Protective of Human Health and Environment Rank
RA 1	No Action, HC	Moderately Protective
RA 2	HC, ICs	Protective
RA 3	HC, ICs, SVE	Protective
RA 4	HC, ICs, SVE, HD	Protective
RA 5a	HC, ICs, SVE Steam Injection over focused treatment area with hot floor	Protective (but higher risk*)
RA 6a	HC, ICs, SVE, ERH over focused treatment area without hot floor	Protective (but higher risk*)

Notes:
HC = Hydraulic containment
ICs = Institutional controls
SVE = Soil vapor extraction
HD = Hydraulic displacement
ERH = Electrical resistance heating

*Higher risk of uncontrolled contaminant migration and fugitive emissions

For all RAs, human health is protected by controlling the exposure pathways. Exposure to contaminants at surface will be addressed by the remedy for soil, and exposure to dissolved-phase contaminants are addressed by the remedy for groundwater. The hydraulic containment component of this RA (required by the remedy for groundwater) protects the environment by controlling migration of contaminants in the dissolved-phase, and DNAPL mass is slowly reduced over time by dissolution. Additionally, the extent of DNAPL is fully within the TI Waiver Zone and occurs almost entirely at the Montrose Property.

RA 1 is considered moderately protective because it does not include institutional controls restricting site activities with the potential for human exposure to DNAPL-impacted soils. However, institutional controls required for the soil and groundwater remedies are expected to restrict similar activities and will likely overlap.

RAs 2 through 4 are protective of human health and the environment. The institutional controls component of this RA provides additional protectiveness by restricting Site access and uses that may result in exposure to DNAPL-impacted soils. RA 3 protects the environment by removing the source of VOCs and DNAPL in the permeable unsaturated zone (PVS and unsaturated UBA) overlying groundwater. RA 4 protects the environment by removing mobile DNAPL from the saturated UBA by hydraulic displacement, reducing the risk of DNAPL migration either laterally within the UBA or downward into the BFS. Candidate well spacings of 25 and 50 feet are considered for this hydraulic displacement RA and are less than computer modeled distances of 120 feet. Additionally, computer modeling of hydraulic displacement predicted that no DNAPL would be mobilized past the basal silty sand member of the UBA or to the underlying BFS assuming DNAPL pool heights up to 8 feet.

RAs 5a and 6a would be protective of human health and the environment but both present an increased risk of adverse consequences associated with remedy excursion or upset conditions. As described in Sections 5.2.6 and 5.2.7, there is an increased risk of contaminant migration associated with thermal remediation, particularly steam injection. Uncontrolled steam distribution can result in lateral spreading and a reduction in the protectiveness of RA 5a. Any lateral spreading of contaminants to the north and underneath the adjacent commercial building at the former Boeing Realty Corporation property would reduce the protectiveness of RAs 5a and 6a. Additionally, there is an increased risk of downward migration associated with steam injection. If not effectively recovered, the DNAPL may migrate downward into the BFS. In addition, dissolved-phase contaminants may be mobilized either laterally or downward if steam condensate is not effectively recovered. While the mass of dissolved MCB in condensed steam would be substantially lower than that in DNAPL, it still has the potential to impact the BFS in concentrations significantly higher than what is currently present in the BFS. Although RA 5a includes implementation of a hot floor within the underlying BFS, the effectiveness of a steam injection hot floor in the underlying aquifer is uncertain and has not been implemented at a comparable site. Also, a significant amount of greenhouse gases (an estimated 14 to 46 million pounds) would be emitted to the environment as a result of RAs 5a and 6a, contributing to global warming. An estimated 88,500 to 297,400 trees would be required to offset the greenhouse gas emissions from RAs 5a and 6a (i.e., based on carbon sequestration capability of trees; Appendix I). California law recognizes that the potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the State from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other human health-related problems (Health & Safety Code §38501(a)).

7.2 COMPLIANCE WITH ARARS

All but one of the RAs complies with DNAPL ARARs, but two of the RAs do not meet global warming TBCs as follows:

Compliance With ARARs Ranking

			Estimated Carbon Footprint	
RA	**Components**	**ARARs Rank**	**GHG Emissions (pounds)**	**Trees Required to Offset GHG Emissions**
RA 1	No Action, HC	Does Not Comply	0 MM	0
RA 2	HC, ICs	Complies	0 MM	0
RA 3	HC, ICs, SVE	Complies	2.2 MM	14,200
RA 4	HC, ICs, SVE, HD	Complies	4.2 MM	27,300
RA 5a	HC, ICs, SVE, Steam Injection over focused treatment area and with hot floor	Complies except for GHG TBCs	46.0 MM	297,400
RA 6a	HC, ICs, SVE, ERH over focused treatment area and without hot floor	Complies except for GHG TBCs	14.0 MM	88,500

Notes:
GHG = Greenhouse gases (carbon dioxide emissions)
MM = millions

The No Action RA, which excludes institutional controls, may not comply with Land Use Covenant requirements established under CCR Title 22 and the California Civil Code, although these requirements will likely be met through the soil remedy. RA 1 would not comply with DNAPL ARARs, unless institutional controls implemented through the soil remedy addressed DNAPL exposure pathways. However, RAs 2, 3, and 4 all comply with ARARs. RAs 3 and 4 include SVE with ex-situ vapor treatment, and field pilot testing has already demonstrated the ability of disposable carbon to comply with air emission ARARs including the Clean Air Act and SCAQMD regulations. Further, RAs 1 through 4 have either a zero or relatively small carbon footprint and would comply with EPA green remediation initiatives and the California Global Warming Solutions Act. All RAs would comply with waste management ARARs under CFR Title 40 and CCR Title 22.

RAs 5a and 6a would comply with ARARs, except for the global warming initiatives. The thermal remediation components of RAs 5a and 6a require a large amount of energy to implement (up to 244,000 MCF and 7,640 megawatt-hours respectively). As a result, the carbon footprints for these remedies are high. The carbon footprint for RA 5a (46 million pounds of GHG emissions and 297,400 trees) is the highest of all the RAs considered and 10 to 20 times higher than RAs 3 and 4. The carbon footprint for RA 6a (14 million pounds of GHG emissions and 88,500 trees) is the second highest of all the RAs considered and 5 to 10 times higher than RAs 3 and 4. Unlike other RAs, a steam boiler is required for RA 5a and would also need to comply with air emission ARARs. Additionally, there is an increased risk of excursions, upset conditions, or fugitive emissions under thermal remediation RAs 5a and 6a, which may not comply with ARARs. Re-injection of treated groundwater into the BFS and Gage Aquifer off-Property would comply with Groundwater ROD in-situ groundwater standards.

The Obama Administration has communicated the intent to further regulate GHG emissions on a federal level. The high GHG emissions generated by RAs 5a and 6a are not consistent with the Obama Administration's stated plans to reduce GHG emissions nationwide (perhaps worldwide) in an effort to mitigate the effects of global warming. If a thermal remedy were implemented at both the Montrose and Del Amo Superfund Sites, the combined GHG emissions would have an even more significant conflict with State and Federal efforts to reduce GHG emissions. Also, depending on the RA selected, it is possible that the cleanup would be captured by future State and/or Federal cap-and-trade regimes. If the cleanup is subject to a cap-and-trade regime and cannot reduce its GHG emissions as required by the regime, then the cleanup may be required to purchase emission offsets at currently unknown prices (assuming such offsets are even available) or be subject to enforcement actions.

Temporary on-Site accumulation of liquid-phase DNAPL would be required for RAs 4 through 6a. The aboveground collection tank would have to comply with hazardous materials storage regulations under CFR Title 40 and CCR Title 22. The liquid-phase DNAPL is also a potentially flammable liquid that would require compliance with City of Los Angeles Fire Department regulations governing collection tanks.

7.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

Long-term effectiveness for all the RAs would be achieved through hydraulic containment and dissolution. DNAPL mass is slowly reduced over time, and the estimated timeframes required to meet ARARs in the UBA were estimated as follows:

Long-Term Effectiveness and Permanence Ranking

RA	Components	Long-Term Effectiveness Rank	Estimated HC Timeframe (years)
RA 1	No Action, HC	Moderately Effective	4,900
RA 2	HC, ICs	Moderately Effective	4,900
RA 3	HC, ICs, SVE	Effective	4,900
RA 4	HC, ICs, SVE, HD	Effective	4,600-4,700
RA 5a	HC, ICs, SVE, Steam Injection over focused treatment area and with hot floor	Effective but with risks	4,300-4,500
RA 6a	HC, ICs, SVE, ERH over focused treatment area and without hot floor	Effective but with risks	4,300-4,500

Notes:
Containment timeframes estimated as described in Section 5.1.1 and Appendix H
Estimated reduction in MCB mass shown in Section 7.4

It is acknowledged that there is uncertainty with the numbers presented. However, these estimates are reasonable and useful for the purposes of comparing the technologies and for assessing the impacts of the various remedies on the operating duration of the groundwater containment system. Furthermore, although some level of uncertainty exists in certain of the selected input parameter values, the sensitivity analysis that H+A conducted bounds the probable range of values, and selected values generally provide low-end estimates of timeframe (H+A, 2009c; Appendix G). Under any reasonable assumptions, the containment timeframe will exceed 1,000 years and likely more than 3,000 years (containment timeframes under 100 years is technically impracticable). Additionally, fine-grained low permeability layers can store significant amounts of dissolved-phase mass which is released very slowly over time (i.e., back diffusion), even after DNAPL in the source zone has been removed. Although the methods used to estimate containment timeframes do not consider back diffusion, the containment timeframes are not expected to be significantly under-estimated since DNAPL dissolution over thousands of years is a more significant driving factor than back diffusion.

For all RAs, an insufficient amount of DNAPL mass would be removed in the short-term to significantly reduce the timeframe required for hydraulic containment in the long-term. Although RAs 5a and 6a have the potential to remove the most MCB mass, the timeframe required for residual contaminant dissolution (the factor that dictates the duration of operation of the containment system) is not meaningfully reduced by these remedies, and these RAs may offer little advantage over RA 4 in terms of containment duration. Some residual DNAPL will be left in-situ, both inside and outside the focused treatment area, and will serve as a continuing source of dissolved-phase contamination to groundwater in the long-term. An estimated 284,200 pounds of MCB and DDT (primarily DDT) will be left within the focused treatment area following steam injection. Reduction of the timeframe required to meet ARARs is a fundamental objective of source area RAs such as RAs 4, 5a, and 6a. However, since the timeframe is not meaningfully reduced, there is limited cost-benefit in implementing a source area RA.

While thermal remediation removes more MCB mass than hydraulic displacement, hydraulic displacement is likely to remove more mobile DNAPL mass and will certainly remove DNAPL-phase DDT mass that thermal remediation would otherwise leave in place. The thermal remediation technologies preferentially remove the volatile or MCB component of the DNAPL, leaving the DDT component behind. However, hydraulic displacement works within the existing DNAPL architecture to remove mobile DNAPL composed of both MCB and DDT. Approximately 88,700 pounds of DDT would be removed by hydraulic displacement under RA 4, assuming 80% mass removal efficiency, which would otherwise be left in-situ by the thermal remediation RAs. Additionally, thermal RAs 5a and 6a present increased risks of contaminant mobilization, which change the DNAPL architecture and could affect the long-term effectiveness of the hydraulic containment remedy component.

RAs 1 and 2 are only considered moderately effective in the long-term because these RAs do not include any source area VOC or DNAPL mass reduction. Under RAs 1 and 2, long-term effectiveness is fully dependent on the hydraulic containment component of the remedies.

7.4 REDUCTION OF TOXICITY, MOBILITY, AND/OR VOLUME OF HAZARDOUS CONSTITUENTS

In the long-term, all of the RAs slowly reduce both the volume and mobility of the DNAPL in the saturated UBA via dissolution and hydraulic containment. The toxicity of the DNAPL-impacted soils is also reduced in the long-term. In the short-term, DNAPL mass is reduced for the RAs as summarized below:

Estimated MCB/DNAPL Mass Removal in Short-Term

	Unsaturated Zone Estimated Mass Removal (lbs) 261,000 lbs MCB Present	Saturated UBA Estimated Mass Removal (lbs) 221,800 lbs Mobile DNAPL Present (RA 4)* 236,800 lbs MCB in DNAPL-phase (RAs 5a and 6a)*			Estimated Mass Removal Total for Unsaturated and Saturated Zones
Assumed Removal Efficiency →	95%	80%			
DNAPL Component →	MCB	MCB	DDT	Total	Total
RA 1	0	0	0	0	0
RA 2	0	0	0	0	0
RA 3	248,000	0	0	0	248,000
RA 4	248,000	88,700	88,700	177,400	425,500
RA 5a	248,000	189,500	>0	>189,500	>437,500
RA 6a	248,000	189,500	0	189,000	437,500

Notes:
* = in Focused Treatment Area; MCB assumed to be 50% of total DNAPL mass; excludes dissolved-phase mass
RA 4a will remove liquid-phase DNAPL consisting of both MCB and DDT.
RA 5a and 6a will remove primarily MCB, volatile component of DNAPL; RA 5a will remove some DNAPL-phase DDT (>0); unable to estimate more precisely.
RA 1 includes No Action and hydraulic containment
RA 2 includes hydraulic containment and institutional controls
RA 3 includes hydraulic containment, institutional controls, and SVE
RA 4 includes hydraulic containment, institutional controls, SVE, and hydraulic displacement of mobile DNAPL
RA 5a includes hydraulic containment, institutional controls, SVE, and steam injection within a focused treatment area
RA 6a includes hydraulic containment, institutional controls, SVE, and ERH within a focused treatment area

Reduction of DNAPL mobility is an RAO for this FS, and the above mass removal table does not distinguish between mobile and residual DNAPL. Therefore, the estimated mass of mobile DNAPL removed by the candidate RAs is summarized as follows:

Estimated Mobile DNAPL Mass Removal in Short-Term

	Saturated UBA Estimated Mobile DNAPL Mass Removal (lbs) 221,800 lbs Mobile DNAPL Present		
Assumed Removal Efficiency →	80%		
DNAPL Component →	MCB	DDT	Total
RA 1	0	0	0
RA 2	0	0	0
RA 3	0	0	0
RA 4	88,700	88,700	177,400
RA 5a	<110,900	>0	<110,900
RA 6a	<110,900	0	<110,900

Notes:
RAs 5a and 6a will remove less than 100% of the mobile MCB mass
RA 5a will remove some DNAPL-phase DDT (>0); unable to estimate more precisely

RAs 1 and 2 do not reduce the toxicity, mobility, or volume of the DNAPL in the short-term. However, in the short-term, RAs 3 through 6a include an accelerated rate of DNAPL volume and mobility reduction within source areas. RAs 3 through 6a include reduction of VOC/DNAPL volume and mobility in the unsaturated zone by SVE, where an estimated 261,000 pounds of MCB is present. A relatively high percent of the MCB is expected to be removed from the permeable unsaturated soils by SVE, and therefore, mass removal efficiencies of 90% and 95% were assumed for this FS. Between 234,900 and 248,000 pounds of MCB may be removed from the unsaturated zone by SVE under RAs 3 through 6a.

RAs 4 through 6a include reduction of DNAPL volume and mobility in the saturated UBA by hydraulic displacement, steam injection, or ERH. The thermal remediation technologies under RAs 5a and 6a will primarily remove the volatile component of the DNAPL (i.e., MCB), leaving the majority of the DDT in-situ. To compare the performance of each RA on an equivalent basis, the mass reduction for the MCB component of the DNAPL is additionally identified for RA 4. Since DDT is relatively insoluble in groundwater, it does not pose a significant risk to groundwater and does not contribute to the duration required for hydraulic containment in the long-term.

Although RA 4 would not reduce MCB mass as much as RAs 5a and 6a, it would significantly reduce the mobile DNAPL mass and would very likely reduce DNAPL mobility to residual levels. Once at residual saturation, the DNAPL would be immobile in the environment (except as a source of dissolved-phase MCB). DNAPL/water capillary pressure testing (Section 2.1.2 and Appendix B) suggests that elevated capillary pressures would be required to displace the final 1% to 1.5% of mobile DNAPL (e.g., 18.9% to

20.4% DNAPL saturations). Therefore, high mass removal efficiencies approaching 100% are unlikely for RA 4. However, an 80% mass removal efficiency is considered reasonable for RA 4, particularly if a high well density scenario is used for this RA. Assuming 80% mobile DNAPL mass reduction, an estimated 177,400 pounds of liquid-phase DNAPL (MCB+DDT) would be removed by RA 4. The estimated amount of MCB mass reduction under RA 4 would therefore be 88,700 pounds. Furthermore, RA 4 works within the existing DNAPL architecture and would remove the most DNAPL-phase DDT of all RAs under consideration. Approximately 88,700 pounds of DDT would be removed by hydraulic displacement under RA 4, assuming 80% mass removal efficiency, which would otherwise be left in-situ by the thermal remediation RAs.

There is an estimated 473,700 pounds of DNAPL, both mobile and residual, present within the focused treatment area and subject to remediation by RAs 5a and 6a. Thermal remediation would preferentially remove the volatile or MCB portion of the DNAPL, estimated at 236,800 pounds within the focused treatment area. Given the characteristics of the Montrose Site, e.g., a complex geologic setting with pooled DNAPL located in highly layered and heterogeneous aquitard underlain by a sandy aquifer, a large volume of soil to be remediated, complex DNAPL composition, and the depth of the treatment zone, thermal remediation is not expected to achieve a high rate of MCB mass removal, and thermal has not been demonstrated at a comparable site. The potential effectiveness of thermal remediation at the site is highly uncertain given the complexity of the site and the unusual DNAPL. Based on the above, removal of even 80 to 90 percent of the DNAPL mass is considered an optimistic, high-end assumption for mass removal by a thermal remedy at the site. Additionally, an estimated 284,200 pounds of MCB and DDT (primarily DDT) would be left within the focused treatment area following steam injection.

RA 4 would most likely remove more mobile DNAPL than thermal remediation RAs 5a an 6a. Because the thermal remedies do not preferentially remove mobile DNAPL, it is not possible to estimate what fraction of the estimated 189,500 pounds of MCB removed by the thermal remedies would have originated as mobile DNAPL. However, even if 100% of the mobile MCB were removed by the thermal remedies (110,900 pounds), it would be less mobile mass than would be potentially removed under RA 4 (177,400 pounds).

Although RAs 5a and 6a would reduce DNAPL mobility in the long-term, thermal remediation increases DNAPL mobility in the short-term. DNAPL viscosities and densities are reduced by heating, making liquid-phase DNAPL more mobile. Both steam injection and ERH mobilize vapor-phase contaminants by volatilization of the MCB component of the DNAPL. Steam injection also mobilizes liquid-phase DNAPL through displacement and has the potential to spread contaminants either laterally or vertically unless all displaced contaminants are effectively recovered. The well spacing proposed by EPA for steam injection (60 feet) is larger than the well spacing for hydraulic displacement (25 to 50 feet) and ERH (21 feet). As a result, of the source area RAs under consideration, RA 5a has the greatest potential of not fully recovering displaced or mobilized contaminants. Additionally, steam injection concentrates the DNAPL saturation at the steam front, increasing the DNAPL mobility. By comparison, hydraulic displacement (RA 4) continuously depletes DNAPL saturation, making the remaining DNAPL less and less mobile over time. Subsurface temperatures will remain elevated beyond the duration of the thermal remedy, and it may take years for temperatures to cool back to ambient conditions. Residual DNAPL left in-situ following thermal treatment would remain partially heated and subject to potential mobilization, even after thermal remediation system operations are terminated.

There is also an increased potential for migration of liquid-phase DDT under thermal remediation RAs 5a and 6a. At temperatures above the melting point (108.5°C), DDT has the potential to be mobilized as a liquid, either laterally or vertically. Steam injection temperatures (>120°C) would be above the DDT melting point. The co-boiling point for the Montrose DNAPL at the base of the UBA (approximately 112-116°C) would also be above the melting point of DDT. The liquid-phase DDT, if mobilized, has the potential to carry some MCB with it. Once the subsurface cools or the liquid-phase DDT moves into a cooler area, it would precipitate as a solid. As an insoluble solid, the DDT would be immobile in the environment.

Additionally, the ability of steam injection and ERH to reduce the volume of DNAPL at the Site has not been pilot tested and is therefore uncertain. The saturated UBA is highly layered, and steam will preferentially flow through the higher permeability sand layers. Heating of the less permeable soils by steam injection may be problematic. For this reason, steam injection was not assembled into a formal RA at the Del Amo Superfund Site where the lithology of one NAPL-impacted area is similar to the Montrose Site (the lithology at two of the NAPL-impacted areas is not similar). Although ERH was assembled into a formal RA at the Del Amo Site, the conditions at that site are different and remedy evaluation at that site should not be considered a precedent for the Montrose Site for the reasons set forth in Section 5.2.7.

Steam injection and ERH have never been applied to a DNAPL site where either MCB or DDT was a primary component of the DNAPL. Despite the relatively high co-boiling point of MCB (compared with other VOCs), the amount of steam to be injected as part of RA 5a was reduced to between 2 and 3 pore volumes as a result of EPA comments. However, lower energy and steam delivery to the saturated UBA will result in lower reductions in DNAPL mass/volume. At the Savannah River Site, steam has been injected for a period of 40 months (3.3 years) to remediate a PCE/TCE DNAPL (with a co-boiling point

<88°C), and the amount of steam injected into the subsurface is approximately 2.5 times the model-predicted amount for that site. Had steam injection been terminated at the target energy consumption, less than 60% of the DNAPL removed to date would have been recovered from the Savannah River site. Similarly, steam was injected at the SCE Visalia Site for a duration of 3 years, and SCE has reported that "approximately 8" pore volumes of steam were flushed through the primary DNAPL-impacted aquifer (the Intermediate Aquifer). Based on these two case sites, steam flushing of 2 to 3 pore volumes may not be adequate to remove even 80% to 90% of the DNAPL-phase MCB at the Montrose Site.

For RA 6a, the target treatment interval of 45 feet is thicker than typically implemented for ERH, increasing the potential for non-uniform or inadequate heating (particularly at depth). ERH has not been implemented over thick saturated zones at sites that are comparable to Montrose. As indicated in Section 6.1.6, achieving target temperatures at depth within the saturated zone has proven to be problematic at several ERH case sites, including the Paducah Gaseous Diffusion Plant in Kentucky. Soil temperatures of only 30°C to 70°C were achieved between 95 and 105 feet bgs at the Paducah Site because the thick treatment interval resulted in poor performance of the deep electrodes. The excessive weight of the steel shot backfill resulted in structural failure of the insulating materials used to separate each of six electrical elements. The electrodes functioned as a single element with no vertical differentiation, and as a result, were not effective in heating the deeper soils. If ERH is unable to heat the deeper soils at the Montrose Site (also to 105 feet bgs) to target temperatures, DNAPL volume and mobility will not be effectively reduced.

The toxicity of the unsaturated soils and soil gas at the Site is reduced by SVE for RAs 3 through 6a. MCB concentrations and sorbed mass will be significantly reduced in unsaturated soils (25 to 60 feet bgs), resulting in a reduced soil exposure toxicity. The reduced MCB mass in the unsaturated zone will additionally result in reduced MCB concentrations in soil gas, reducing the soil gas exposure toxicity at depth (25 to 60 feet bgs). However, relatively high MCB concentrations in shallow soils within the low permeability PD (4 to 25 feet bgs) will remain in-situ following DNAPL remedy implementation. This shallow PD VOC-impacted soil is being addressed by the Soil FS. Additionally, although DNAPL mass will be reduced from the saturated UBA, the toxicity of the saturated UBA soils will not be completely reduced as residual DNAPL will remain in place (in varying quantities) following remedy implementation, regardless which RA is selected. In the long-term, the toxicity of the DNAPL-impacted soils is further reduced through dissolution and hydraulic containment.

7.5 SHORT-TERM EFFECTIVENESS

RAs 1 through 4 are effective in the short-term, and RAs 5a and 6a are potentially effective although there would be increased risks in the protectiveness of these thermal remediation RAs in the short-term.

Short-Term Effectiveness Ranking

RA	Components	Short-Term Effectiveness Rank
RA 1	No Action, HC	Moderately Effective
RA 2	HC, ICs	Effective
RA 3	HC, ICs, SVE	Effective
RA 4	HC, ICs, SVE, HD	Effective
RA 5a	HC, ICs, SVE, Steam Injection over focused treatment area and with hot floor	Potentially Effective (but higher risk)
RA 6a	HC, ICs, SVE, ERH over focused treatment area and without hot floor	Potentially Effective (but higher risk)

In the short-term, all of the RAs would protect human health by controlling the contaminant exposure pathways, and all the RAs would protect the environment through hydraulic containment. Although RA 1 does not include institutional controls for DNAPL-impacted soils, the institutional controls required for the soil and groundwater remedies will overlap the DNAPL-impacted soils to some degree resulting in a moderate level of protection for the No Action RA. RAs 3 and 4 additionally include SVE and would protect human health by treating soil vapors ex-situ with disposable carbon/resin. Disposable carbon/resin is identified as the lowest cost treatment technology for these RAs and was highly effective in meeting air emission ARARs during SVE field pilot testing in 2003. Additionally, this vapor treatment technology does not involve any combustion processes (such as thermal oxidation), steam-regeneration processes (such as with on-site carbon/resin regeneration), or any on-Site storage of condensed VOCs/DNAPL (such as with steam-regenerable carbon/resin). Spent carbon/resin is removed for off-Site recycling or disposal. Disposable carbon/resin is the least complex vapor treatment technology and is a reliable method for protecting human health and the environment during remedy implementation. Under RA 4, DNAPL is extracted by hydraulic displacement for temporary on-Site accumulation pending off-Site disposal. To ensure protection of human health and the environment in the short-term, DNAPL would be collected in a dual-contained tank with engineering controls to prevent over-filling and automatically detect leaks.

RAs 5a and 6a would potentially be effective in protecting human health and the environment in the short-term but have higher risks associated with remedy excursions. Displaced DNAPL, contaminated steam condensate, and heated MCB vapors must be effectively recovered in order to prevent contaminant migration in the subsurface, either laterally outside the focused treatment area or downward into the underlying BFS. Potential contaminant migration underneath the adjacent commercial building located at the former Boeing Realty Corporation property would reduce the protectiveness of RAs 5a and 6a in the short-term. Compared with ERH and hydraulic displacement, steam injection has a lower well density, and therefore, has the greatest risk of not effectively recovering all mobilized contaminants during remedy implementation. Additionally, there is an increased mobilization risk associated with installation of the 36 hot floor wells required under RA 5a or the 182 total electrode locations, multiphase extractions wells, and temperature monitoring points required under RA 6a. Downward migration of DNAPL as a result of well installation activities, particularly if into the BFS, would not be protective of the environment in the short-term.

With thermal remediation RAs 5a and 6a, there is an increased potential for heated vapors or contaminated steam to be accidentally released to atmosphere as a fugitive emission. The higher temperatures and pressures associated with RAs 5a and 6a can result in aboveground piping failure or accelerated corrosion. Similarly, contaminated steam or vapors can escape to surface through previously drilled borings or wells that are not able to withstand the elevated temperatures associated with RAs 5a and 6a. For example, at the SCE Visalia site, one well suffered a catastrophic failure due to incompatibility of the bentonite annular seal materials with the elevated temperatures of the full-scale steam remedy (Lawrence Livermore National Laboratory, 1999), releasing steam, hot water, and sediment into the atmosphere. It may be necessary to re-abandon several former soil borings or replace some existing wells in order to prevent fugitive releases to atmosphere during remedy implementation. Additionally, the subsurface will remain hot even if remediation system operations are interrupted. VOC vapors would continue to be generated in-situ even with the remediation system off. Long periods of system downtime, without adequate soil vapor recovery, have the potential to cause VOC migration in the unsaturated zone. Fugitive emissions, if any, during remedy implementation would reduce the protective of RAs 5a and 6a in the short-term.

7.6 IMPLEMENTABILITY

Four of the RAs are readily implementable, while two of the RAs would be difficult to implement as follows:

Implementability Ranking

RA	Components	Implementability Rank
RA 1	No Action, HC	Implementable
RA 2	HC, ICs	Implementable
RA 3	HC, ICs, SVE	Implementable
RA 4	HC, ICs, SVE, HD	Implementable
RA 5a	HC, ICs, SVE, Steam Injection over focused treatment area and with hot floor	Difficult To Implement
RA 6a	HC, ICs, SVE, ERH over focused treatment area and without hot floor	Difficult To Implement

RAs 1 through 4 are readily implementable. Access restrictions are already being implemented at the Site and will be addressed as part of the Soil FS. A Land Use Covenant could be established at the Montrose Property, where nearly all of the DNAPL is located. SVE is a widely implemented technology, and disposable carbon/resin is readily available for ex-situ vapor treatment. The implementability of hydraulic displacement has already been demonstrated through field pilot testing, with moderate DNAPL recovery rates observed in all wells within the mobile DNAPL footprint. The Montrose DNAPL can be readily separated from groundwater using standard techniques. A relatively low level of maintenance would be required for RAs 3 and 4, and specialized equipment or contractors are not required. Routine maintenance could be implemented to abate equipment fouling from precipitates, and routine well redevelopment could be implemented to restore hydraulic conductivities of the extraction/injection wells. Although the in-situ groundwater standards would need to be waived for re-injecting untreated groundwater under RA 4, EPA previously waived these requirements for DNAPL extraction pilot testing.

RAs 5a and 6a would be more difficult to implement than the other RAs. Thermal remediation projects require a large amount of infrastructure to heat the subsurface, recover contaminants, and treat or dispose of contaminants ex-situ. A large number of wells are required for thermal remediation projects (up to 182 combined electrode locations and wells for ERH) and would generate a significant amount of waste requiring management and disposal. Under RAs 5a and 6a, ex-situ treatment of groundwater with subsequent re-injection off-Property into the BFS and Gage Aquifer would be required because re-injection into the UBA would cool the subsurface and reduce the effectiveness of those remedies. The re-injection flow requirement of the DNAPL remedy would need to be considered during design of the Groundwater Remedy Treatment System to accommodate this additional quantity of water. RAs 5a and 6a would require a high level of maintenance, including boiler maintenance, water pre-conditioning, and brine disposal (for RA 5a only). RAs 5a and 6a would also require highly skilled field operators and specialized technology vendors (and license holders for steam injection). Although there are three qualified technology vendors available for ERH, steam injection is implemented far less frequently and only one qualified vendor (TerraTherm) is still pursuing steam injection as a commercial technology. Praxis Environmental is a small, independent one-person firm with insufficient resources to implement a project of this size. Currently, there are only four active steam injection sites in the United States: (1) the Pacific Wood Treating Site in Port of Ridgefield, Washington, (2) the Savannah River M Settling Basin Site in Aiken, South Carolina, (3) the Williams Air Force Base OU2 Site in Mesa, Arizona (a pilot TEE project), and (4) the Northrop (formerly TRW) Site in Danville, Pennsylvania. However, none of these sites are comparable to the Montrose Site as indicated in Section 5.2.6 and Appendix L. For RA 5a, a hot floor would be required in the BFS to reduce the potential for downward migration, but hot floors are very infrequently implemented and would increase the complexity of the RA. For example, it is noted that a hot floor is not being employed at any of the four currently active steam injection sites. Additionally, hot floor wells require specialized drilling methods to isolate the DNAPL-impacted zone during drilling. Also, due to the higher mass removal rates, RAs 5a and 6a would require use of either a steam-regenerable carbon/resin or thermal oxidation ex-situ vapor treatment system. These ex-situ vapor treatment technologies are more complex and require additional maintenance and management of additional waste streams not otherwise required by the other RAs.

7.7 COST

Costs for the six RAs ranged from \$1.1 to \$25.8 MM NPV (Table 6.1 and Appendix J) as follows:

Cost Ranking

RA	Components	Cost Rank	Estimated NPV Cost	Unit NPV Cost
RA 1	No Action, HC	No Cost	\$1.1 MM	NA
RA 2	HC, ICs	Low	\$1.3 MM	NA
RA 3	HC, ICs, SVE	Low to Moderate	\$5.9 MM	\$19/lb removed by SVE
RA 4[1]	HC, ICs, SVE, HD	Moderate	\$11.7 MM	\$33-\$40/lb removed by HD
RA 5a[2]	HC, ICs, SVE, Steam Injection over focused treatment area with hot floor	High	\$24.6-\$25.8 MM	\$110-\$116/lb removed by steam injection
RA 6a[2]	HC, ICs, SVE, ERH over focused treatment area without hot floor	High	\$21.2-\$22.9 MM	\$92-\$101/lb removed by ERH

Notes:
NA = not applicable; no mass reduction in short-term
Unit cost reflects NPV cost of remedial component (i.e., SVE, HD, steam, or ERH) divided by estimated mass reduction in pounds (lb); unit cost does not reflect sum of all remedy components.
All RAs include costs for long-term hydraulic containment (HC), including RA 1.
[1]HD costs reflect an assumed range for well spacing.
[2]In accordance with EPA cost reconciliation discussions, the estimated cost for RAs 5a and 6a includes both low and high cost scenarios consistent with an assumed range for energy consumption and well spacing.

RA 2 is the lowest cost RA that meets the threshold requirements of protecting human health and the environment and complying with ARARs. However, RA 2 does not include any accelerated DNAPL mass or mobility reduction in the short-term. Under RA 2, DNAPL mass and mobility would be reduced in the long-term by the hydraulic containment component of the RA.

RAs 3 and 4 are the lowest cost RAs that both meet the threshold requirements and reduce DNAPL mass/mobility in the short-term. DNAPL mass and mobility would be reduced by SVE in the permeable unsaturated zone under both RAs. An estimated 261,000 pounds of MCB is present in the permeable unsaturated zone and available for removal by SVE. Assuming a 95% mass removal efficiency, SVE would recover an estimated 248,000 pounds of MCB from the permeable unsaturated soils. As an accelerated mass reduction remedy component, the estimated unit cost of SVE in the permeable unsaturated zone (excluding ICs) is \$19 NPV per pound of MCB.

DNAPL mass and mobility would be reduced by HD in the saturated UBA under RA 4. An estimated 221,800 pounds of mobile DNAPL (MCB and DDT) are present at the Site and available for removal by HD. Assuming a 80% mass removal efficiency, HD would recover an estimated 177,400 pounds of DNAPL, of which 88,700 pounds are assumed to be MCB. As an accelerated mass reduction remedy component, the estimated unit cost of HD assuming a 50-foot well spacing (excluding SVE and ICs) is \$33 NPV per pound of DNAPL or \$65 NPV per pound of MCB. The estimated unit cost of RA 4 assuming a 25-foot well spacing (i.e., higher well density scenario) is \$13.0 MM NPV. Therefore, the estimated unit cost of HD (excluding SVE and ICs) assuming a 25-foot well spacing is \$40 NPV per pound of DNAPL or \$80 per pound of MCB.

RAs 5a and 6a are the highest cost RAs that meet the threshold requirements and reduce DNAPL mass in the short-term. Under these RAs, DNAPL mass would be reduced by either steam injection or ERH in the saturated UBA. DNAPL mobility is increased in the short-term by these thermal remediation technologies but would be reduced in the long-term, once the subsurface cools to ambient conditions (which may take years). An estimated 236,800 pounds of DNAPL-phase MCB, both residual and mobile, are present within the UBA focused treatment area and available for removal by thermal remediation. An estimated 189,500 pounds of MCB would be removed by RAs 5a and 6a assuming an 80% mass removal efficiency, which Montrose believes is conservatively high given the nature of the DNAPL and the complex lithology of the UBA. As an accelerated mass reduction remedy component, the estimated unit cost of steam injection (excluding SVE and ICs) is \$110 to \$116 NPV per pound of MCB for the low and high cost scenarios respectively. The estimated unit cost of ERH (excluding SVE and ICs) is \$92 to \$101 NPV per pound of MCB for the low and high cost scenarios respectively. The unit costs of MCB mass removal for steam injection (RA 5a) and ERH (RA 6a) are approximately twice that of hydraulic displacement (RA 4).

There is no, or limited, cost benefit associated with the accelerated source area treatment by thermal remediation. RAs 5a and 6a are estimated to cost \$9.5 to \$14.1 MM NPV more than RA 4. RAs 5a and 6a have the potential to remove more MCB mass than RA 4, and yet, the timeframe required for hydraulic containment is not meaningfully reduced by these remedies (as indicated in Section 7.3). In fact, if delivery of only 2 to 3 pore volumes of steam results in a lower mass removal efficiency, as indicated by the experience at the Savannah River Site and SCE Visalia Site, the hydraulic containment timeframes for RAs 4 and 5a would largely remain the same. None of the RAs can remove a sufficient amount of DNAPL to meaningfully reduce the timeframe required for hydraulic containment, and therefore, the increased cost of RAs 5a and 6a is not justified. If up to 8 pore volumes of steam flushing were required at the Montrose Site (as was required at the SCE Visalia Site), the cost of RA 5a would be increased by approximately \$8 MM NPV to a range of \$32.6 to \$33.8 MM NPV. The increased natural gas consumption from the additional steam flushing would also increase the carbon footprint from approximately 46 to 80 million pounds of greenhouse gases (a 74% increase in the GHG emissions). Given the heterogeneous UBA and complicated DNAPL architecture, the Montrose Site may require more pore volumes of steam flushing than the SCE Visalia Site, not less. Additionally, RAs 5a and 6a present a significantly higher risk of contaminant spreading, downward migration, and/or fugitive emissions. Neither of the thermal remediation technologies has been pilot tested at the site, and the potential effectiveness is highly uncertain.

Further, climate change regulation is expected to increase the costs of both natural gas and electricity because upstream suppliers of these commodities are expected to be regulated at both the State and Federal level. In other words, as a price is placed on carbon emissions, whether directly via a carbon tax or, more likely, indirectly via State and/or Federal cap-and-trade regimes, the cost of carbon-intensive forms of energy (e.g., natural gas and non-renewably generated electricity) will increase. Such increased costs would add additional cost to RAs utilizing natural gas and/or purchasing electricity.

In comparison, the cost of long-term hydraulic containment is estimated at $1.1 MM NPV as indicated in Section 6.2.1. Assuming a discount rate of 4%, it is noted that costs incurred after approximately Year 350 do not contribute even $1 to the NPV total. As a result, there is no difference in the NPV cost of long-term hydraulic containment between estimated timeframes of 4,400, 4,600, or 4,900 years. Unless the timeframe is below approximately 350 years, the NPV cost of long-term hydraulic containment would be unchanged. The cost of source depletion under RAs 5a and 6a ($21.2 to $25.8 MM NPV) is significantly higher than the cost of long-term hydraulic containment ($1.1 MM NPV). In accordance with the decision criteria established by an expert panel in 2003 (*The DNAPL Remediation Challenge: Is There a Case for Source Depletion,* EPA, 2003), source depletion may not be needed at the Montrose Site. There is little to no cost benefit of implementing a $21.2 to $25.8 MM NPV thermal source zone depletion remedy if long-term hydraulic containment will still be required for an estimated 4,400 years.

7.8 STATE ACCEPTANCE

This criterion cannot be evaluated until the State has commented on the draft DNAPL FS and Proposed Plan. Therefore, evaluation of this criterion is deferred and will be addressed by EPA in the ROD. As a result, all RAs are ranked equally for State Acceptance (i.e., Not Applicable).

7.9 PUBLIC ACCEPTANCE

This criterion cannot be evaluated until the public has commented on the draft DNAPL FS and Proposed Plan. However, public concerns expressed at other Superfund Sites in Southern California are well documented, and therefore, Montrose has offered some preliminary comments regarding possible public acceptance of the candidate RAs.

Public Acceptance Ranking

RA	Components	Public Acceptance Rank	Ex-Situ Vapor Treatment	DNAPL Storage and T&D	Heated Soil Vapors and Steam
RA 1	No Action, HC	May Accept	No	No	No
RA 2	HC, ICs	May Accept	No	No	No
RA 3	HC, ICs, SVE	May Accept	Yes	No	No
RA 4	HC, ICs, SVE, HD	May Accept	Yes	Yes	No
RA 5a	HC, ICs, SVE, Steam Injection over focused treatment area and with hot floor	May Not Accept	Yes	Yes	Yes
RA 6a	HC, ICs, SVE, ERH over focused treatment area and without hot floor	May Not Accept	Yes	Yes	Yes

At other Southern California Superfund Sites, the public has expressed concerns regarding air emissions, specifically the potential for emission of PICs including dioxins and furans. The public has additionally expressed concerns about hazardous waste accumulation, handling, and transportation. The RAs were evaluated for their compatibility with these public concerns.

RAs 1 and 2 are most likely to be acceptable to the public. Under these RAs, no accelerated VOC or DNAPL mass reduction would take place. None of the hazardous constituents are brought to surface for ex-situ treatment, collection, or handling. Conversely, all hazardous constituents remain in the subsurface, eliminating the possibility for human exposure as a result of site remediation activities (i.e., ex-situ vapor treatment or hazardous waste storage/handling). Human health is protected by controlling the contaminant exposure pathways. The remedy for soil will protect human health from contaminant exposure at surface. The environment is protected by hydraulic containment, which reduces DNAPL mass in the long-term and prevents migration of dissolved-phase contaminants outside the TI Waiver Zone. Hydraulic containment is a required component of the remedy for groundwater (for which a ROD was issued in 1999).

RAs 3 and 4 may be acceptable to the public. Ex-situ soil vapor treatment is required as part of the SVE component for the remedy. Disposable carbon/resin is estimated to be the most cost-effective for these RAs, which is a treatment technology that has been accepted by the public at other Superfund Sites. This treatment technology does not include combustion processes capable of generating dioxins or furans. Through field pilot testing, the activated carbon has been shown to be highly effective in treating vapor-phase contaminants at the Site. The extracted vapors are at ambient temperatures, not heated, and not prone to accelerated corrosion/wear of piping and equipment. Additionally, the spent carbon is not thermally regenerated on-Site using steam. Spent carbon is transported off-Site for disposal or recycling at a permitted facility, eliminating the risk of human exposure or fugitive emission from on-Site carbon recycling. Under RA 3, no liquid-phase DNAPL is extracted for ex-situ accumulation and handling. Under RA 4, liquid-phase DNAPL is extracted, temporarily accumulated on-Site, and transported off-Site every 90 days (or less) for incineration. However, the volume of DNAPL collected and handled at the Property is lower than for RAs 5a and 6a.

RAs 5a and 6a may not be accepted by the public. These thermal remediation technologies have the greatest potential for upset conditions, excursions, and fugitive emissions. Fugitive emissions have occurred at other thermal remediation sites and are a legitimate concern. In one instance, material incompatibility led to pipe failure, releasing contaminated vapors and steam to atmosphere. Heated vapors and steam can also migrate to surface via former soil borings or wells if not constructed with materials resistant to thermal heating. For example, at the SCE Visalia site, one well suffered a catastrophic failure due to incompatibility of the bentonite annular seal materials with the elevated temperatures of the full-scale steam remedy (Lawrence Livermore National Laboratory, 1999). Steam flow to surface was so significant as to disperse sediment up to 200 feet from the well, a portion of which impacted off-site areas. Further, heated soil vapors and steam can escape through leaks in piping fittings (threads or flanges), through vacuum blower seals, or through ground surface (through cracks in the asphalt or concrete) at sites with shallow applications. The subsurface will remain hot even if remediation system operations are interrupted, and VOC vapors would continue to be generated in-situ even with the remediation system off. Long periods of system downtime, without adequate soil vapor recovery, have the potential to cause VOC migration in the unsaturated zone. VOCs not effectively recovered during implementation of this RA will re-condense in cool areas of the Site, potentially outside of the treatment area footprint. Following treatment, the subsurface may remain hot for years, posing a VOC migration risk far beyond the duration of the thermal remedy.

The public may also not accept RAs 5a and 6a because of the high greenhouse gas emissions and contribution to global warming. Additionally, under RAs 5a and 6a, steam-regenerable carbon/resin or thermal oxidation would be used for ex-situ vapor treatment, which may not be as acceptable to the public as the disposable carbon/resin would be for RAs 3 and 4. Finally, the public may not accept RAs 5a and 6a due to the increased risks of contaminant mobilization in the subsurface, either laterally within the UBA or vertically downward into the underlying BFS.

7.10 SUMMARY OF COMPARATIVE ANALYSIS

A summary of the comparative analysis for the six RAs is provided below:

SUMMARY OF COMPARATIVE ANALYSIS

NCP Criterion	RA 1	RA 2	RA 3	RA 4	RA 5a	RA 6a
Protection of Human Health and Environment	Yes but no ICs	Yes	Yes	Yes	Yes But has risks	Yes But has risks
Compliance with ARARs	No	Yes	Yes	Yes	Yes (except for global warming)	Yes (except for global warming)
Carbon Footprint, lbs GHG →	(0 MM)	(0 MM)	(2.2 MM)	(4.2 MM)	(46 MM)	(14 MM)
Trees required to offset GHG →	(0 trees)	(0 trees)	(14,200 trees)	(27,300 trees)	(297,400 trees)	(88,500 trees)
Long-Term Effectiveness	Effective	Effective	Effective	Effective	Effective But has risks	Effective But has risks
Containment Timeframe→	4,900 years	4,900 years	4,900 years	4,600-4,700 years	4,300-4,500 years	4,300-4,500 years
Reduction of Toxicity, Mobility, or Volume (in short-term)						
Unsaturated Zone MCB Mass Reduction[c] →	0 lbs	0 lbs	248,000 lbs	248,000 lbs	248,000 lbs	248,000 lbs
Saturated UBA MCB Mass Reduction[d] →	0 lbs	0 lbs	0 lbs	88,700 lbs	189,500 lbs	189,500 lbs
Total MCB Mass Reduction →	**0 lbs**	**0 lbs**	**248,000 lbs**	**336,700 lbs**	**437,500 lbs**	**437,500 lbs**
Saturated UBA DDT Mass Reduction[d] →	0 lbs	0 lbs	0 lbs	88,700 lbs	>0 lbs[a]	0 lbs
Total MCB+DDT Mass Reduction →	**0 lbs**	**0 lbs**	**248,000 lbs**	**425,400 lbs**	**>437,500 lbs[a]**	**437,500 lbs**
Mobile MCB+DDT Mass Removal→	**0 lbs**	**0 lbs**	**0 lbs**	**177,400 lbs**	**<110,900 lbs[b]**	**<110,900 lbs[b]**
Short-Term Effectiveness	Effective	Effective	Effective	Effective	Potentially Effective	Potentially Effective
Implementability	Implementable	Implementable	Implementable	Implementable	Difficult to implement	Difficult to implement
Cost (MM NPV)	$1.1	$1.3	$5.9	$11.7	$24.6-$25.8	$21.2-$22.9
Unit Cost ($/lb removed) →	NA	NA	$19/lb	$33-$40/lb	$110-$116/lb	$92-$101/lb
State Acceptance	NA	NA	NA	NA	NA	NA
Public Acceptance	May Accept	May Accept	May Accept	May Accept	May Not Accept	May Not Accept

Notes:

ICs = Institutional Controls
SVE = Soil Vapor Extraction
SF = Steam Flushing
MM = million
HC = Hydraulic Containment
HD = Hydraulic Displacement
ERH = Electrical Resistance Heating
GHG = Greenhouse Gases
NA = Not Applicable
NPV = Net Present Value
Lbs = pounds
[d]80% mass removal assumed for HD (mobile only), steam, and ERH
[a]Some DNAPL-phase DDT will be removed by RA 5a
[b]Will not remove >100% of mobile MCB mass
[c]95% MCB mass removal assumed for SVE

Although the DNAPL remedy will not be selected by EPA until after the public comment period, Montrose has identified a preferred RA based on the detailed evaluation in Section 6 and comparative analysis in Section 7. The preferred RA and rationale for selecting this RA is provided below for consideration.

7.11 MONTROSE PREFERRED REMEDIAL ALTERNATIVE

Summary Discussion

RA 4 is identified as the Montrose preferred RA for DNAPL. RA 4 includes four components:

- Hydraulic containment (long-term)
- Institutional controls
- SVE in the permeable unsaturated zone (short-term)
- Hydraulic displacement in the saturated UBA (short-term)

The first two remedy components, hydraulic containment and institutional controls, protect human health and the environment both in the short and long-term. Fundamental compliance with the NCP threshold criteria are met by these two remedy components in the long-term. The second two remedy components, SVE and hydraulic displacement, reduce DNAPL mass and mobility in the short-term, which are RAOs for DNAPL. SVE reduces VOC/DNAPL mass and mobility in the unsaturated zone, while hydraulic displacement reduces DNAPL mass and mobility in the saturated UBA. RA 4 meets and complies with all six of the DNAPL RAOs as follows:

- RAO No. 1: *Prevent human exposure to DNAPL constituents that would pose an unacceptable health risk to on- or off-Property receptors under industrial land uses of the Montrose plant property and adjacent properties.* RAO No. 1 is met by the institution controls and hydraulic containment components of RA 4.
- RAO No. 2: *To the extent practicable, limit uncontrolled lateral and vertical migration of mobile NAPL under industrial land use and hydraulic conditions in groundwater.* The potential for DNAPL migration in the short and long-term, either laterally or vertically, is significantly reduced or eliminated by the hydraulic displacement component of RA 4, which would significantly reduce DNAPL mobility and would likely remove the most mobile DNAPL mass.

- RAO No. 3: *Increase the probability of achieving and maintaining containment of dissolved-phase contamination to the extent practicable, as required by the existing groundwater ROD, for the time period that such containment remains necessary.* The probability of achieving and maintaining hydraulic containment of dissolved-phase contaminants in the long-term is increased by SVE and hydraulic displacement components of RA 4.

- RAO No. 4: *Reduce NAPL mass to the extent practicable.* The SVE and hydraulic displacement components of RA 4 reduce NAPL mass within the unsaturated zone (25-60 feet bgs) and saturated zone (60-105 feet bgs).

- RAO No. 5: *To the extent practicable, reduce the potential for recontamination of aquifers that have been restored by the groundwater remedial actions, as required by the groundwater ROD, in the event containment should fail.* The potential for recontamination of aquifers outside the TI Waiver Zone, in the event that hydraulic containment should fail, is reduced by the hydraulic displacement component of RA 4.

- RAO No. 6: *To the extent practicable, reduce the dissolved-phase concentrations within the containment zone over time.* The hydraulic containment component of RA 4 reduces dissolved-phase concentrations over time.

Detailed Discussion of Preferred Remedy Components

Institutional Controls

The institutional controls component of the remedy protects human health by controlling the exposure pathways. Human exposure to DNAPL-impacted soils would be restricted by a Land Use Covenant, and access to the Site would continue to be restricted. Restrictions would additionally be placed on groundwater use within the TI Waiver Zone.

SVE

The SVE component of the remedy protects the environment by removing an estimated 248,000 pounds of MCB from the permeable unsaturated zone assuming a 95% mass removal efficiency. If left in place, a portion of this MCB mass may leach downward over time to groundwater within the UBA. Therefore, removal of the MCB mass from permeable unsaturated soils overlying groundwater by SVE increases the protectiveness of the remedy and increases the certainty of hydraulic containment effectiveness.

Other favorable aspects of SVE for this remedial action include:

- The unit cost to implement SVE in the permeable unsaturated soils is the lowest of all source area remedial components at approximately $19 NPV per pound of MCB.
- SVE is readily implementable and does not require a high level of maintenance or specialty equipment/contractors.
- Ex-situ vapor treatment using disposable carbon was demonstrated to be highly effective in removing vapor-phase Site contaminants (and complying with air emission ARARs) during field pilot testing and is expected to be acceptable to the public.
- Soil vapors would not be treated ex-situ using thermal oxidation, so there is no potential for formation of PICs such as dioxins and furans.
- SVE would control vapor-phase migration in soil gas.

Hydraulic Displacement

RA 4 protects the environment by removing an estimated 177,400 pounds of mobile DNAPL or 88,700 pounds of MCB from the saturated UBA (assuming an 80% mass removal efficiency). Of the candidate RAs, RA 4 would likely remove the most mobile DNAPL. Even if RAs 5a and 6a removed 100% of the mobile MCB mass (an estimated 110,900 pounds), it would still be less than the mass of mobile DNAPL potentially removed under RA 4. RA 4 would remove an estimated 88,700 pounds of DNAPL-phase DDT (assuming an 80% mass removal efficiency) that thermal remediation RAs 5a and 6a would, for the most part, leave in the subsurface. Furthermore, there are significant doubts about the potential removal efficiency of steam injection and ERH at the Montrose Site. During 2-dimensional bench-scale testing, only 42% of the DNAPL mass and 64% of the MCB mass was removed by steam injection (University of Toronto, 2009).

More importantly, RA 4 would significantly reduce the mobility of the DNAPL in the short-term, and in doing so, significantly increases the probability of hydraulic containment being effective in the long-term. Hydraulic displacement is a depleting technology that continuously reduces the mobility of DNAPL (unlike steam injection and ERH). Hydraulic displacement has been field pilot tested and the results conclusively demonstrated that DNAPL can be mobilized for extraction. Mobile DNAPL was effectively recovered from all test locations within the estimated mobile DNAPL footprint, and the fact that hydraulic displacement can mobilize the Montrose DNAPL for extraction is irrefutable. Initial DNAPL recovery rates were moderate and are expected to increase with increased hydraulic gradients. Computer modeling has demonstrated that the proposed 50-foot well spacing for hydraulic displacement is expected to be effective, indeed, modeling predicted that well spacings up to 80-feet would be effective. Computer modeling has also predicted that DNAPL would not migrate below the basal silty sand layer of the UBA (and into the BFS) by implementation of hydraulic displacement assuming DNAPL pool heights up to 8 feet. Hydraulic displacement is readily implementable and does not require a high level of maintenance or specialty equipment/contractors.

Costs

RA 4 is the lowest cost RA that reduces the DNAPL mass and mobility within the saturated UBA in the short-term. The total cost of RA 4 is estimated at $11.7 MM NPV and is $9.5 to $14.1 MM NPV lower than thermal remedy based RAs 5a and 6a. The estimated unit cost of hydraulic displacement is $65 NPV per pound of MCB with a 50-foot well spacing, which is approximately half the estimated unit cost of steam injection ($110-$116 NPV per pound of MCB) and ERH ($92-$101 NPV per pound of MCB). There is minimal or no difference in the estimated containment timeframes between the remedies (up to 7%), and long-term hydraulic containment will be required under any RA because none will be able to remove sufficient DNAPL to meaningfully reduce containment duration. Therefore, further consideration of RAs 5a and 6a on the basis of cost does not appear justified.

Implementation Risk

RA 4 does not include the risks associated with thermal remediation or the uncertainties of not having field pilot tested those technologies. Under RA 4, there would be <u>no</u> thermal heating, <u>no</u> potential for fugitive emissions of heated vapors or steam, <u>no</u> potential for uncontrolled displacement of DNAPL at the steam front, and <u>no</u> potential for downward migration of contaminants from steam condensate. The infrastructure required for RA 4 would be significantly less and much simpler than the thermal-based RAs 5a and 6a, thereby reducing the potential for upset conditions or excursions to adversely impact the protectiveness of human health and the environment.

Global Environment

RA 4 would not contribute to global warming as significantly as RAs 5a and 6a. The carbon footprint of RA 4 is 5 to 10 times lower than that of either RAs 5a or 6a, both of which would consume a large amount of natural gas or electricity. RA 4 would comply with global warming TBCs, while thermal remediation RAs 5a and 6a would not. Given the Obama Administration commitment to reducing GHG emissions, the recently proposed EPA GHG reporting policy (March 2009), and numerous GHG bills introduced in Congress that are likely to ultimately result in a national cap-and-trade regime, the importance of selecting remedies that meet these TBCs is expected to increase.

Current climate models are predicting significant warming by the year 2100. The Intergovernmental Panel on Climate Change (IPCC), a scientific intergovernmental body established by the World Meteorological Organization and the United Nations Environment Programme (UNEP) in 1988, issued a Fourth Assessment of GHG emissions and predictions in 2007. The IPCC Fourth Assessment concluded that there is a >90% chance that the increase in globally averaged temperatures since the mid-20th century is due to the observed increase in anthropogenic greenhouse gas levels. The Fourth Assessment Report predicted that, by year 2100, global mean surface temperatures would rise between 1.1°C and 6.4°C under varying scenarios. The Fourth Assessment Report also predicted corresponding mean sea level rises up to 0.59 meters by year 2100, although this estimate was considered conservative since it did not consider significant melting of the Greenland and Antartic ice sheets.

The Massachusetts Institute of Technology (MIT) Joint Program recently revised its global climate model, an Integrated Global System Model (IGSM), increasing the estimated median temperature increase by year 2100 from 2.4°C to 5.1°C (MIT, 2009). The model additionally predicts a median sea level rise of 0.44 meters by year 2100. MIT Joint Program Co-Director Ronald Prinn recently testified to the U.S. House of Representatives in February 2007 regarding global warming trends and predictions.

Dr. Christopher Field, Director of the Carnegie Institution for Science and Co-Chair for Working Group II of the IPCC, recently testified before the U.S. Senate in February 2009. In his testimony, Dr. Field indicated that "the data now show that greenhouse gas emissions are accelerating much faster than we thought". Dr. Field indicated that the annual rate of increase in carbon dioxide emissions was 3.5% per year during the period 2000 to 2007, as compared with a rate of 0.9% per year for the period from 1990 to 1999. By the year 2080, Dr. Field indicated that "many millions more people are projected to be flooded every year due to sea-level rise".

While DNAPL will remain a source of groundwater contamination for many centuries at the Montrose Site, even under an aggressive thermal source area remedy, significant climate changes may occur within the next 90 years due primarily to the effects of global warming caused by GHG emissions. Thermal remediation technologies consume high quantities of energy, either electrical or natural gas, resulting in large power generation-based GHG emissions and carbon footprints. The deleterious effects of the increased GHG emissions outweigh the potential environmental benefits of removing DNAPL-phase

MCB in the short-term. As recognized by a draft federal climate change bill recently introduced by Representatives Waxman and Markey, "Each increment of emission, when combined with other emissions, causes or contributes materially to the acceleration and extent of global warming and its adverse effects for the lifetime of such gas in the atmosphere. Accordingly, controlling emissions in small as well as large amounts is essential to prevent, slow the pace of, reduce the threats from, and mitigate global warming and its adverse effects." (American Clean Energy and Security Act of 2009 at Section 701(a)(2)). RA 4, which would generate 5 to 10 times fewer GHG emissions, is likely to remove the most mobile DNAPL mass and would significantly reduce DNAPL mobility. DNAPL RAOs can be met by RA 4 without emitting significant GHG to the atmosphere, unlike thermal remediation RAs 5a and 6a.

Summary

In summary, RA 4 meets DNAPL RAOs, complies with ARARs, and protects human health and the environment. RA 4 is effective in both the short and long-term, reduces DNAPL mass and mobility in both the unsaturated and saturated zones, and is readily implementable. RA 4 is the lowest cost of the three RAs that reduce DNAPL mass/mobility in the saturated UBA (i.e., RA 4, 5a, and 6a). RA 4 is less complex, less uncertain, and has significantly less risk than RAs 5a and 6a. RA 4 is also expected to be acceptable to the public. For these reasons, the Montrose preferred remedy for DNAPL is RA 4.

Section 8.0

References

8.0 REFERENCES

Basel, 2006. *Evaluation of Thermal Remediation Technologies, Cabot Carbon/Koppers Superfund Site, Gainesville, Florida.* Haley & Aldrich, Inc. December 19.

CDWR, 1961. *Planned Utilization of the Ground Water Basins of the Coastal Plain of Los Angeles County,* Appendix A: Ground Water Geology. Bulletin 104 (California Department of Water Resources).

CH2M Hill, 2007. Memorandum to Jeff Dhont, US EPA Region 9. *Responses to EPA Focus Questions Pertaining to the Application of Thermal Treatment and Hydraulic Displacement at DNAPL Sites*. November 9.

Christ, et. al., 2005. *Coupling Aggressive Mass Removal with Microbial Reductive Dechlorination for Remediation of DNAPL Source Zones: A Review and Assessment*, Environmental Health Perspectives, Vol. 113.

Davis, 2006. *Final Report and Addendum, One-Dimensional Thermal Remediation Treatability Study, Montrose Chemical Superfund Site, Los Angeles County, California*. August 24.

Earth Tech, 1999a. *Final Report, Sewer Sediment Removal Action, Montrose Chemical Corporation*. March 29.

Earth Tech, 1999b. *Soil Feasibility Study, Montrose Superfund Site, Los Angeles, California*. September.

Earth Tech, 2003. *Buried Concrete Debris and DDT-Impacted Soil Volumetric Estimates*, *Montrose Superfund Site*. March 3.

Earth Tech, 2004a. *Soil Vapor Extraction Pilot Test Report, Montrose Superfund Site*. June 28.

Earth Tech, 2004b. *Revised HiPOx Pilot Test Report, Montrose Superfund Site*. September 23.

Earth Tech, 2004c. *Revised Soil Gas Survey Report, Montrose Superfund Site*. October 13.

Earth Tech, 2005. *Final Revised Field Sampling Plan, Supplemental Soil Investigation, Montrose Superfund Site, Torrance, California*. March 11.

Earth Tech, 2007a. *Revised Draft Workplan for Two Dimensional Bench Scale Evaluation of DNAPL Mobility During Steam Flushing, Montrose Superfund Site*. September 7.

Earth Tech, 2007b. Documentation Package, On- and Near-Property Supplemental Soil Investigation, Montrose Superfund Site. September 17.

Earth Tech, 2007c. *Revised Draft Workplan for Bench-Scale Evaluation of Electrical Resistance Heating for the Removal of DNAPL from the Upper Bellflower Aquitard, Montrose Superfund Site*. October 10.

Earth Tech, 2007d. Letter to Mr. Jeffrey Dhont, EPA, *List of Thermal Remediation Case Study Sites*, Montrose Superfund Site. November 12.

Earth Tech, 2007e. Letter to Mr. Jeffrey Dhont, EPA, *Estimated Hydraulic Displacement Remedy Costs, Montrose Superfund Site*. November 12.

Earth Tech, 2007f. Letter to Mr. Jeffrey Dhont, EPA, *Estimated Thermal Remediation Costs, Montrose Superfund Site.* November 12.

Earth Tech, 2008a. *Addendum to the Revised Workplans for Two Dimensional Bench Scale Evaluation of DNAPL Mobility During Steam Flushing and Electrical Resistance Heating*, Montrose Superfund Site, Torrance, California. February 21.

Earth Tech, 2008b. Technical Memorandum to Joe Kelly, Montrose Chemical Corporation, *DNAPL Focused Treatment Area Evaluation, Saturated Upper Bellflower Aquitard (UBA), Montrose Superfund Site.* June 5.

Earth Tech, 2008c. Technical Memorandum to Joe Kelly, Montrose Chemical Corporation, *Revised DNAPL Steam Injection Cost Evaluation for the Montrose Superfund Site, Torrance, California.* July 21.

Earth Tech, 2008d. Technical Memorandum to Joe Kelly, Montrose Chemical Corporation, *DNAPL Focused Treatment Area Steam Injection Cost Evaluation for the Montrose Superfund Site, Torrance, California.* July 31.

Earth Tech, 2008e. Technical Memorandum to Joe Kelly, Montrose Chemical Corporation, *Revised DNAPL Electrical Resistance Heating (ERH) Cost Evaluation for the Montrose Superfund Site, Torrance, California.* August 7.

Earth Tech, 2008f. Technical Memorandum to Joe Kelly, Montrose Chemical Corporation, *DNAPL Focused Treatment Area Electrical Resistance Heating (ERH) Cost Evaluation for the Montrose Superfund Site, Torrance, California.* August 22.

Earth Tech, 2008g. *Geotechnical and Chemical Evaluation, Groundwater Treatment Plant Site Soils, Montrose Superfund Site.* October 29.

Earth Tech, 2008h. *UV-Oxidation Bench-Scale Testing Report and Cost Comparison – HiPOx and UV-Oxidation, Montrose Superfund Site.* November 7.

Earth Tech, 2008i. *Liquid-Phase Granular Activated Carbon Bench-Scale Testing Report and Cost Projection, Montrose Superfund Site.* November 11.

Earth Tech, 2008j. *Technical Memorandum to Joe Kelly, Montrose Chemical Corporation, DNAPL Well UBE-5, Montrose Superfund Site, Torrance, California.* November 13.

EPA, 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final.* October.

EPA, 1989a. Second Amendment, Administrative Order of Consent, EPA Docket No. 85-04 *Montrose Chemical Superfund Site – Issuance of CERCLA Unilateral Administrative Oder for Sampling Activities – U. S. EPA Region 9 CERCLA Docket No. 85-04.*

EPA, 1989b. *CERCLA Compliance With Other Laws Manual: Interim Final (Parts I and II).* EPA/540/G-89/006. August.

EPA, 1995. Manual, *Bioventing Principles and Practice, Volume II: Bioventing Design*, EPA 540/R-95/534-a, Office of Research and Development. September.

EPA, 1998. *Final Remedial Investigation Report for the Montrose Superfund Site, Los Angeles, California.* May 18.

EPA, 1999. *Record of Decision for Dual Site Groundwater Operable Unit, Montrose Chemical and Del Amo Superfund Sites, Volume I: Declaration and Decision Summary*. March 1999.

EPA, 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, EPA 540-R-00-002. July.

EPA, 2002. Partial Consent Decree No. CV 90-3122-R. Relating to the Neighborhood Areas. June 24.

EPA, 2003. *The DNAPL Remediation Challenge: Is There a Case for Source Depletion?* Expert Panel on DNAPL Remediation, EPA Contract No. 68-C-02-092. December.

EPA, 2004a. *Draft Report Former Montrose Plant Property Reuse Assessment.* US EPA Contract No. 68-W-98-225. CH2M Hill, Inc. and Team Subcontractors. January.

EPA, 2004b. *EPA Region 9 Preliminary Remediation Goals (PRGs), Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites*, RSL Table Update. October.

EPA, 2006. *Abstracts of Remediation Case Studies*, Volume 10, Federal Remediation Technologies Roundtable, EPA-542-R-06-002. August.

EPA, 2007. Letter to Mr. Joe Kelly, Montrose Chemical Corporation, *EPA Comments on Interrelationship of the Montrose Site Groundwater, DNAPL, and Soil Remedies Memorandum of April 27, 2007; Transmittal of EPA Groundwater, DNAPL and Soil Remedies Interconnections Analysis; Montrose Chemical Superfund Site, Los Angeles County, CA*. June 29.

EPA, 2008a. Email to Mike Palmer, de maximis, *Thermal Cost Estimates and Request*, August 8.

EPA, 2008b. Letter to Mr. Joe Kelly, Montrose Chemical Corporation, *EPA Comments on Technical Memo: Results of Field Investigation into the Presence of DNAPL in the Bellflower Sand; Montrose Chemical Superfund Site, Los Angeles, CA*. August 17.

EPA, 2008c. *Overall Operational Design Report Based on Well Field Optimization, Dual Site Groundwater Operable Unit Remedial Design, Montrose Chemical and Del Amo Superfund Site*. September.

EPA, 2008d. Letter to Mr. Joe Kelly, Montrose Chemical Corporation, *EPA Comments on Focused Treatment Area Evaluation; Saturated Upper Bellflower Aquitard; Montrose Chemical Superfund Site; Los Angeles County, CA*. September 10.

EPA, 2008e. *EPA Region 9 Preliminary Remediation Goals (PRGs), Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites*, RSL Table Update. September.

EPA, 2008f. *Explanation of Significant Differences for the Silresim Chemical Corporation Superfund Site, Lowell, Massachusetts*. EPA Region 1. September.

EPA, 2008g. Letter to Mr. Joe Kelly, Montrose Chemical Corporation, *EPA Comments on Evaluation of Containment Zone Timeframes Technical Memorandum; Montrose Chemical Superfund Site, Los Angeles County, CA*. December 23.

Falta et al., 2005. *Assessing the impacts of partial mass depletion in DNAPL source zones. I. Analytical of source strength functions and plume response*. Journal of Contaminant Hydrology, 78, 259-280.

Freeze, 2000. *The Environmental Pendulum, A Quest for the Truth about Toxic Chemicals, Human Health, and Environmental Protection*. R. Allan Freeze, Berkeley, California, University of California Press.

Fritz, et.al. 1991. *Toxicity of chlorobenzene on Pseudomonas sp. Strain RHO1, a chlorobenzene-degrading strain*. June 11.

Geosyntec, 2004. *Assessing the Feasibility of DNAPL Source Zone Remediation: Review of Case Studies*. Naval Facilities Engineering Command, Contract Report, CR-04-002-ENV. May.

H+A, 1992. *Groundwater Treatability Test Results, Phase I*, Montrose Site, Torrance, California. February 21.

H+A, 1999. *Dense Non-Aqueous Phase Liquid Feasibility Study*, *Montrose Site, Torrance, California*. September 29.

H+A, 2004a. Technical Memorandum to Mr. Jeffrey Dhont, US EPA, *DNAPL Investigation Results, Bellflower Sand, Montrose Site, Torrance, California*. January 23.

H+A, 2004b. *Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, California, Revision 1.0*. October 22.

H+A, 2004c. *Baseline Groundwater Sampling Results Report*, Montrose Site, Torrance, California, DSGWRD 26 – 027, Revision 1.0. November 22.

H+A, 2005. Letter to Danielle Ondic, H+A, from US Filter, *Montrose Rapid Small Scale Column Test (RSSCT) Results*. October 13.

H+A, 2006a. Technical Memorandum to Susan Keydel, US EPA, *DNAPL Reconnaissance Borings in Support of Earth Tech Soil Sampling Program, Montrose Site, Torrance, California*. January 19.

H+A, 2006b. Technical Memorandum to Mr. Jeffrey Dhont, US EPA, *DNAPL Boiling Test Results, Montrose Site, Torrance, California*. August 7.

H+A, 2007a. *2006 Groundwater Monitoring Results Report, Montrose Site, Torrance, California*. February 28.

H+A, 2007b. Technical Memorandum to Mr. Jeffrey Dhont, US EPA, *Interrelationships of the Montrose Site Groundwater, DNAPL, and Soil Remedies, Montrose Site, Torrance, California*. April 27.

H+A, 2007c. *DNAPL Extraction Test Summary Report*, *Montrose Site, Torrance, California, Revision 1.0*. September 18.

H+A, 2008a. Technical Memorandum to Jeffrey Dhont, US EPA, *Addendum 2 to the Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, California*. February 20.

H+A, 2008b. *Technical Memorandum RE: Results of Depth Discrete Groundwater Sampling of Three Bellflower Sand Wells,* Montrose Superfund Site, Torrance, California. April 14.

H+A, 2008c. Technical Memorandum to Jeffrey Dhont, US EPA, *Results of Field Investigation into the Possible Presence of DNAPL in the Bellflower Sand, Montrose Superfund Site, Torrance, California*. June 24.

H+A, 2008d. *Technical Memorandum to Jeffrey Dhont, US EPA, Geostatistical Analysis of Lithological Continuity, Montrose Superfund Site, Torrance, California*. July 15.

H+A, 2008e. Technical Memorandum to Jeff Dhont, US EPA, *Evaluation of Containment Zone Timeframes Following a DNAPL Remedy at the Montrose Site, Torrance, California,* September 4 and subsequent email, *Lack of Documentation in Containment Zone/Timeframes Following a DNAPL Remedy Tech Memo*. September 9.

H+A, 2008f. Email to Jeff Dhont, US EPA, *DNAPL Thickness Map*. January 22.

H+A, 2008g. *DNAPL Extraction Test Summary Report, Montrose Site, Torrance, California, Revision 2.* June 4.

H+A, 2009a. Technical Memorandum to Jeffrey Dhont, US EPA, *Status of Hydraulic Displacement Modeling, Montrose Site, Torrance, California*. January 15.

H+A, 2009b. *Results of Hydraulic Displacement Modeling, Montrose Site, Torrance, California*. April 6.

H+A, 2009c. Technical Memorandum to Carolyn d'Almeida, US EPA, *Evaluation of Containment Zone Timeframes Following a DNAPL Remedy at the Montrose Site, Torrance, California*, Revision 1.0 and Response to EPA Comments. March 25.

Howard, et al., 1991. *Handbook of Environmental Degradation Rates*, CRC Press.

Koppers Industries, 2001. Material Safety Data Sheet, Creosote, CAS Number 8001-58-9. May.

LACSD, 1968. Plan and Profile, East Torrance Extension Trunk Sewer, Los Angeles County Sanitation District No. 5, Office of Chief Engineer.

Lawrence Livermore National Laboratory, 1999. *Preliminary Analysis of the Failure of Well EW-5, Visalia Pole Yard, February 11, 1999*. R.Aines and R.Newmark. February 11.

Lee and Swindoll, 1993. *Bioventing for in situ remediation*, Hydrological Sciences Journal No. 4.

Levine-Fricke, 1995. *Preliminary Endangerment Assessment (PEA), Jones Chemical Facility, Torrance, California*. Volumes I and II. June 28.

Levine–Fricke, 2008. *Draft Remedial Investigation Workplan, JCI Jones Chemicals, Inc., Torrance, California*. November 21.

Los Angeles, City of, 1996. *Harbor Gateway Community Plan*. December 6.

McCarty, et al., 2003. *Comparison between Donor Substrates for Biologically Enhanced Tetrachloroethene DNAPL Dissolution*, Environmental Science and Technology, Yang Y. and P.L. McCarty.

McGuire et. al., 2006. *Performance of DNAPL Source Depletion Technologies at 59 Chlorinated Solvent-Impacted Sites*, Ground Water Monitoring & Remediation, Winter.

McLaren-Hart, 1997. *Results of the p-CBSA Activated Carbon Treatability Study*. June 4.

MIT, 2009. *Probabilistic Forecast for 21st Century Climate Based on Uncertainties in Emissions (without Policy) and Climate Parameters*. Report No. 169. Massachusetts Institute of Technology Joint Program. January.

Queen's University, 2009. Technical Memorandum to J. Kelly, Montrose, *Summary of Bench-Scale Evaluation of Electrical Resistance Heating for the Removal of DNAPL from the Upper Bellflower Aquitard*. March 17.

She and Sleep, 1999. *Removal of Perchlorethylene from a Layered Soil System by Steam Flushing*, Ground Water Monitoring and Remediation. Spring.

URS, 2008. *Draft Final Soil and NAPL Feasibility Study, Del Amo Superfund Site, Los Angeles, California*. July 18.

University of Toronto, 2009. Letter to Michael Palmer, de maximis. *Update on Two-Dimensional Bench Scale Testing of Steam Flushing*. March 17.

WHO, 2004. *Chlorobenzenes Other Than Hexachlorobenzene: Environmental Aspects*, Concise International Chemical Assessment Document 60, World Health Organization.

Zeneca, SPEL, 1997. *Montrose Natural Attenuation Study*, Sheridan Park Environmental Laboratory, Customer Report No. C97-001. February 24.

Appendix A

A-1 – Chemical Composition of DNAPL from Saturated Upper Bellflower Aquitard

TABLE A-1
CHEMICAL COMPOSITION OF DNAPL FROM SATURATED UBA
MONTROSE SUPERFUND SITE

1988 & 1989 DNAPL COMPOSITION DATA

MW-2	Units	Analyte	
		MCB[(a)]	Total DDT[(b)]
01/21/88	wt %	49	51
03/18/88	wt %	28	72
03/25/88	wt %	74	26
04/22/88	wt %	45	55
10/14/88	wt %	49	51
02/09/89	wt %	52	48

Footnotes (1988 &1989 Data):

(a) = Sample analyzed via EPA Method 8240.
(b) = Sample analyzed by EPA Method 8080.

Total DDT = Total DDT is reported as the sum of the detected concentrations of: 2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT, and 4,4'-DDT.

SOURCE: H+A, 1999. DNAPL Feasibility Study, Montrose Site, Torrance, California. September 29.

1998 DNAPL COMPOSITION DATA

10/29/98	Units[(g)]	Analyte										
		MCB[(c)]	Total DDT[(d)]	Chloroform[(c)]	2-Butanone or MEK[(c)]		Acetone[(c)]		1,4-DCB[(c)]		p-CBSA[(e,g)]	
UBE-1[(f)]	wt %	49 (49)	47.0 (47.8)	0.1 (0.1)	0.5 (ND)	J (R)	1.0 (0.8)	R (R)	0.1 (0.2)	J (J)	0.14	R
UBT-1	wt %	49	49.9	0.1	ND	R	ND	R	0.1	J	0.14	
UBT-2	wt %	49	50.9	ND	ND	R	ND	R	0.1	J	0.14	
UBT-3	wt %	51	47.7	0.4	ND	R	ND	R	0.1	J	0.14	
MW-2[(f)]	wt %	48 (47)	54.5 (48.8)	0.2 (0.2)	ND (ND)	R (R)	ND (ND)	R (R)	0.1 (0.2)	J (J)	0.07	
Average	wt %	49.1	50.2	0.2	0.1		0.2		0.1		0.1	

Footnotes (1998 Data):

(c) = Sample analyzed via EPA Method 8240.
(d) = Sample analyzed by EPA Method 8270 modified.
(e) = Sample analyzed by modified EPA Method 300.
(f) = The duplicate for UBE-1 is a field duplicate quality control sample; the duplicate for MW-2 is a laboratory duplicate quality control sample.
(g) = pCBSA results are presented in units of milligrams per liter. All other results are presented as weight percent.
R = Results qualified as "R" or rejected
J = Results qualified as "J" or estimated
( ) = Values shown in parenthetical represent results of a duplicate sample.

TABLE A-1
CHEMICAL COMPOSITION OF DNAPL FROM SATURATED UBA
MONTROSE SUPERFUND SITE

2008 DNAPL COMPOSITION DATA

UBE-4 / UBT-1[h]	Units	Analyte	
		MCB	Total DDT
2D-DNAPL-A	wt %	64%	36%
2D-DNAPL-AB[i]	wt %	64%	36%

Footnotes (2008 Data):

The DNAPL samples were collected on March 6, 2008.
(h) = DNAPL used for samples was a mixture between wells UBE-4 and UBT-1
All samples were analyzed using EPA Method 8270C modified.

(i) = Sample 2D-DNAPL-AB is a duplicate sample of 2D-DNAPL-A

2009 DNAPL COMPOSITION DATA

UBE-4	Units	Analyte	
		MCB	Total DDT
UBE-4-5	wt %	51%	49%

Footnotes (2009 Data):

All samples were analyzed using EPA Method 8270C modified.

Abbreviations (global):

Total DDT = Total DDT is reported as the sum of the detected concentrations of: 2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT, and 4,4'-DDT.
2,4'-DDD = 2,4'-Dichlorodiphenyldichoroethane
4,4'-DDD = 4,4'-Dichlorodiphenyldichoroethane
2,4'-DDE = 2,4'-Dichlorodiphenyldichoroethylene
4,4'-DDE = 4,4'-Dichlorodiphenyldichoroethylene
2,4'-DDT = 2,4'-Dichlorodiphenyltrichoroethane
4,4'-DDT = 4,4'-Dichlorodiphenyltrichoroethane
1,4-DCB = 1,4-Dichlorobenzene
BHC = Hexachlorocyclohexane
DDT = Dichlorodiphenyltrichloroethane
UBA = Upper Bellflower Aquitard
MEK = Methyl ethyl ketone
mg/kg = Milligrams per kilogram
p-CBSA = Parachlorobenzene sulfonic acid
MCB = Monochlorobenzene
NA = Not analyzed
ND = Not detected
wt % = Weight Percent

Appendix B

B-1 Physical Properties of DNAPL from Saturated Upper Bellflower Aquitard
Lab Report: Capillary Pressure Measurements from PTS Laboratories

TABLE B-1
PHYSICAL PROPERTIES OF DNAPL FROM SATURATED UBA
MONTROSE SUPERFUND SITE
1988-2006

		UBA Well Identifier				
Physical Property	Temperature	UBE-1	UBT-1	UBT-2	UBT-3	MW-2
Density (g/cm^3)	10°C[a]	1.233	1.234	1.239	1.228	NA
	20°C[a]	1.222	1.224	1.229	1.217	NA
	22°C[b]	1.252	1.241	1.252	1.246	1.251
	30°C[a]	1.211	1.214	1.218	1.209	NA
	40°C[a]	1.200	1.202	1.209	1.199	NA
	50°C[a]	1.190	1.194	1.198	1.188	NA
	60°C[a]	1.181	1.186	1.188	1.178	NA
	70°C[a]	1.171	1.174	1.177	1.167	NA
	80°C[a]	1.160	1.163	1.165	1.157	NA
	90°C[a]	1.150	1.154	1.157	1.146	NA
Dynamic Viscosity (cP)	10°C[a]	3.46	3.41	3.43	3.40	NA
	20°C[a]	2.78	2.80	2.81	2.76	NA
	22°C[b]	2.60	2.60	2.70	2.50	2.80
	30°C[a]	2.33	2.33	2.32	2.28	NA
	40°C[a]	2.05	2.03	2.01	2.05	NA
	50°C[a]	1.86	1.93	1.80	1.86	NA
	60°C[a]	1.83	1.93	1.80	1.85	NA
Surface Tension DNAPL (dyn/cm)	10°C[a]	34.5	35.9	35.6	35.1	NA
	50°C[a]	31.1	32.3	32.6	31	NA
	90°C[a]	26.8	27.7	27.6	26.7	NA
Surface Tension Groundwater (dyn/cm)	10°C[a]	67.2	67.3	67.2	63.6	NA
	50°C[a]	61.2	61.3	61.5	59.7	NA
	90°C[a]	56.4	56.7	55.4	54.4	NA
Interfacial Tension DNAPL - Groundwater (dyn/cm)	10°C[a]	11.5	11.4	11.2	11.1	NA
	22°C[b]	15	14	14	15	13
	50°C[a]	11.1	11.1	10.9	11.3	NA
	90°C[a]	11.8	11.4	10.6	11.6	NA
Boiling Point - DNAPL only[1,c]	NA	NA	Initial: 128°C Final: 359°C	NA	NA	NA
Co-Boiling Point - DNAPL/GW mixture[c]	NA	NA	96 °C	NA	NA	NA

BOE-C6-0059999

Footnotes:

1. The boiling point increases as the chlorobenzene component of the DNAPL boils off, eventually reaching a maximum temperature when the DNAPL was likely composed solely of DDT.

Data Sources:

(a) = Data source for table row is: Davis, Eva L., Ph.D., 2006. Final Report, Montrose Chemical Superfund Site, Los Angeles County California, One-Dimensional Thermal Remediation Treatability Study. August 24, 2006.

(b) = Data source for table row is Appendix B of: H+A, 1999. Dense Non-Aqueous Phase Liquid Feasibility Study, Montrose Site, Torrance, California. September 29, 1999.

(c) = Data source is: H+A, 2006b. Technical Memorandum Re: DNAPL Boiling Test Results, Montrose Site, Torrance, California. August 7, 2006.

Abbreviations:

C = Centigrade
cP = centipoise
dyn/cm = dynes per centimeter
g/cm^3 = grams per cubic centimeter
NA = Not analyzed or not applicable
H+A = Hargis + Associates, Inc.
UBA = Upper Bellflower Aquitard

DNAPL/Water Capillary Pressure Data

PTS Laboratories

June 20, 2008

Alycia McCord
Earth Tech, Inc.
300 Oceangate Blvd., Suite 700
Long Beach, CA 90802

Re: PTS File No: 38167
Revised Oil/Water Pc Imbibition Table
Montrose-Torrance

Dear Ms. McCord:

Please find enclosed revised report format for Physical Properties analyses conducted upon cores and fluids received from your Montrose; Torrance project. At the request of Dr. Denise Yaffe the oil/water imbibition capillary pressure table has been changed from reporting absolute pressure values to negative pressure. The note regarding spontaneous imbibition has also been removed.

PTS Laboratories appreciates the opportunity to be of service. If you have any questions or require additional information, please give me a call at (562) 907-3607.

Sincerely,
PTS Laboratories

Michael Mark Brady

Michael Mark Brady, P.G.
Project Manager

Encl.

PTS Laboratories

Project Name: Montrose-Torrance
Project Number: N/A

PTS File No: 38167
Client: Earth Tech, Inc.

TEST PROGRAM

CORE ID	Depth ft.	Core Recovery ft.	Number of Sleeves	Grain Size Analyses	Air/Water Drainage Pc Pkg.	VG Params.	Grain Density API RP 40	DNAPL/H2O Drainage Pc	DNAPL/H2O Imbibition Pc	Notes
		Plugs:		Grab	1" Vert.	calc.	Use A/W	1" Vert.	1" Vert.	
2DSB-1-72	72	1.5	3	X	X	X	X			Horiz. orient. core (cut horiz. plug)
2DSB-1-79	79	1.5	3	X	X	X	X	X	X	Horiz. orient. core (cut horiz. plug)
2DSB-1-88	88	1.5	3	X	X	X	X			Horiz. orient. core (cut horiz. plug)
2DSB-1-82	82	1.5	3	X	X	X	X			Horiz. orient. core (cut horiz. plug)
2DSB-1-65	65	1.0	2	X	X	X	X			Vert. orient. core (cut vert. plug)
2DSB-1-75	75	0.5	1	X	X	X	X			Vert. orient. core (cut vert. plug)
2DSB-1-76	76	1.5	3	X	X	X	X			Horiz. orient. core (cut horiz. plug)
2DSB-1-90	90	1.0	2	X	X	X	X			Horiz. orient. core (cut horiz. plug)
2DSB-1-98	98	1.0	2	X	X	X	X			Horiz. orient. core (cut horiz. plug)
TOTALS:		**11.0**	**22 cores**	**9**	**9**	**9**	**9**	**1**	**1**	

Laboratory Test Program Notes

Hold all samples frozen.
Client wants vertical orientation for all samples. Where core is oriented vertically sub-sample parallel to core. Where core is oriented horizontally sub-sample perpendicular to core. Cores 2DSB-1-65 and 2DSB-1-75 are oriented vertical and the remaining seven are oriented horizontally.
Measure Grain Density on all Air/Water Drainage Capillary Pressure samples.
Use site water for Air/Water Pc tests and hydraulic conductivity measurements.
Use site fluids (DNAPL & water) for DNAPL/Water Pc tests.
Take Grain Size Analysis samples from adjacent to Pc sample locations.
Include wet bulk density measurement in the physical property reports per D. Yaffe/Earthtech 3/31/08.

Fluid received for use in capillary pressure tests (1 pair).

Water ID: MW-3P
Product ID: UBE-4-2

PTS File No: 38167
Client: Earth Tech, Inc.

PHYSICAL PROPERTIES DATA - OIL/WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: oil displacing water)

PROJECT NAME: Montrose-Torrance
PROJECT NO: N/A

Capillary Pressure		Height Above Water Table,	Sample ID	
			2DSB-1-79 at 79 ft.	
			Saturation, % Pore Volume	
psi	cm water	ft	Water	Product
0.000	0.00	0.000	100.0	0.0
0.038	2.69	0.374	100.0	0.0
0.086	6.06	0.841	100.0	0.0
0.153	10.8	1.50	99.3	0.7
0.240	16.8	2.34	98.6	1.4
0.345	24.3	3.37	94.6	5.4
0.470	33.0	4.58	84.4	15.6
0.613	43.1	5.98	75.0	25.0
0.958	67.4	9.35	65.5	34.5
1.38	97.0	13.5	60.1	39.9
1.88	132	18.3	56.7	43.3
2.45	172	23.9	54.7	45.3
3.10	218	30.3	53.3	46.7
3.83	269	37.4	52.0	48.0
8.62	606	84.1	49.3	50.7

Effective Permeability to Water, md.: 452

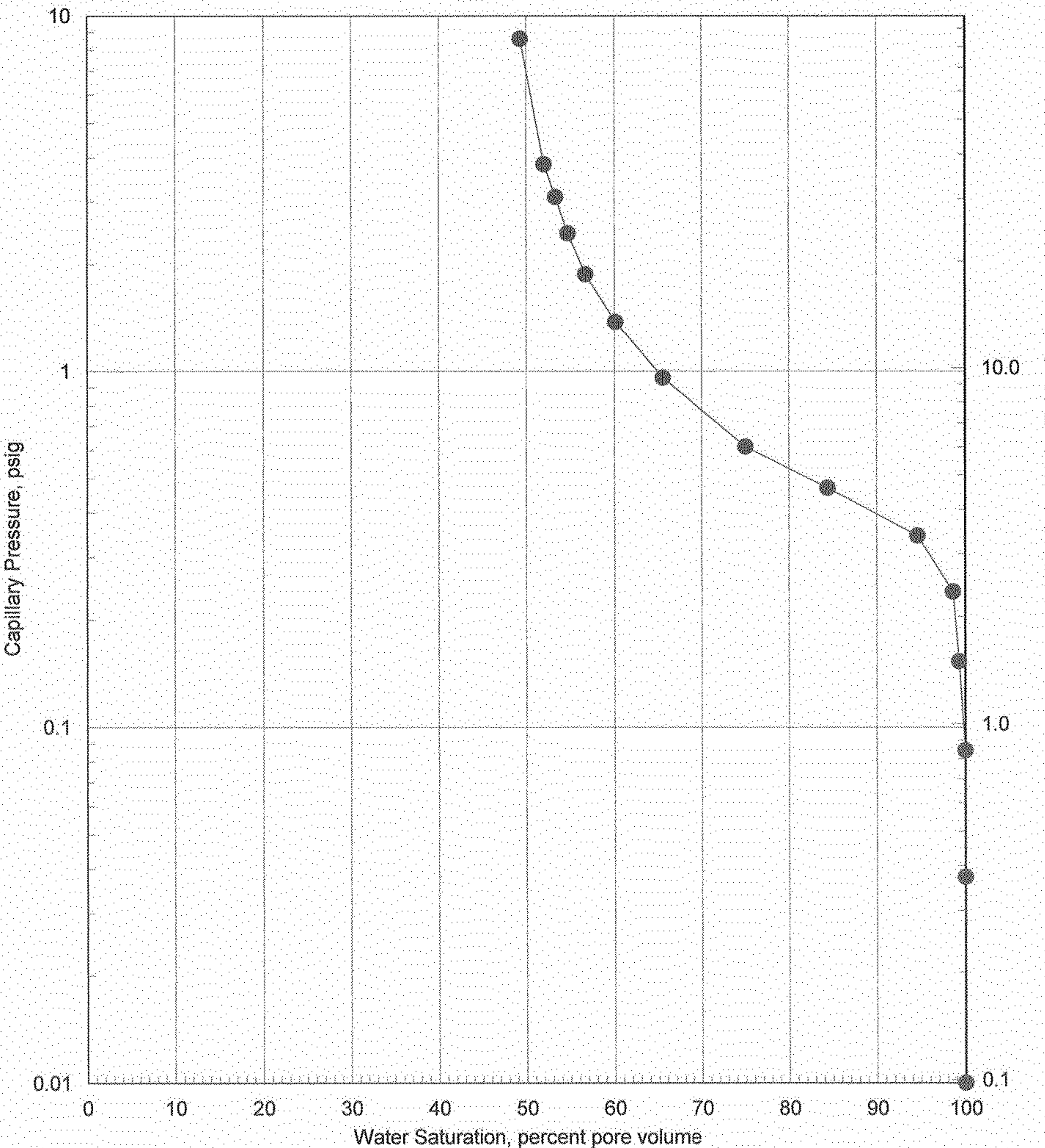
Hydraulic Conductivity, cm/sec: 3.95E-04

Earth Tech Inc.
File No.: 38167

CAPILLARY PRESSURE
Centrifugal Method
Oil Displacing Water System - ASTM D6836

Project Name: Montrose-Torrance
Project Number: N/A

Sample ID: 2DSB-1-79
Depth, ft.: 79



PTS File No: 38167
Client: Earth Tech, Inc.

PHYSICAL PROPERTIES DATA - IMBIBITION CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: water displacing oil)

PROJECT NAME: Montrose-Torrance
PROJECT NO: N/A

Capillary Pressure		Height Above Water Table,	Sample ID **2DSB-1-79 at 79 ft.** Saturation, % Pore Volume	
psi	cm water	ft	Water	Product
0.000	0.00	0.000	49.3	50.7
-0.023	1.59	0.220	59.4	40.6
-0.051	3.57	0.495	70.3	29.7
-0.090	6.34	0.88	74.3	25.7
-0.141	9.91	1.37	76.3	23.7
-0.203	14.3	1.98	77.6	22.4
-0.276	19.4	2.69	78.4	21.6
-0.361	25.4	3.52	79.0	21.0
-0.564	39.6	5.50	79.7	20.3
-0.812	57.1	7.92	80.4	19.6
-1.10	77.7	10.8	80.8	19.2
-1.44	101	14.1	80.9	19.1
-1.83	128	17.8	81.1	18.9
-2.25	159	22.0	81.1	18.9
-5.07	357	49.5	81.1	18.9

Effective Permeability to Water, md.: 452

Hydraulic Conductivity, cm/sec: 3.95E-04

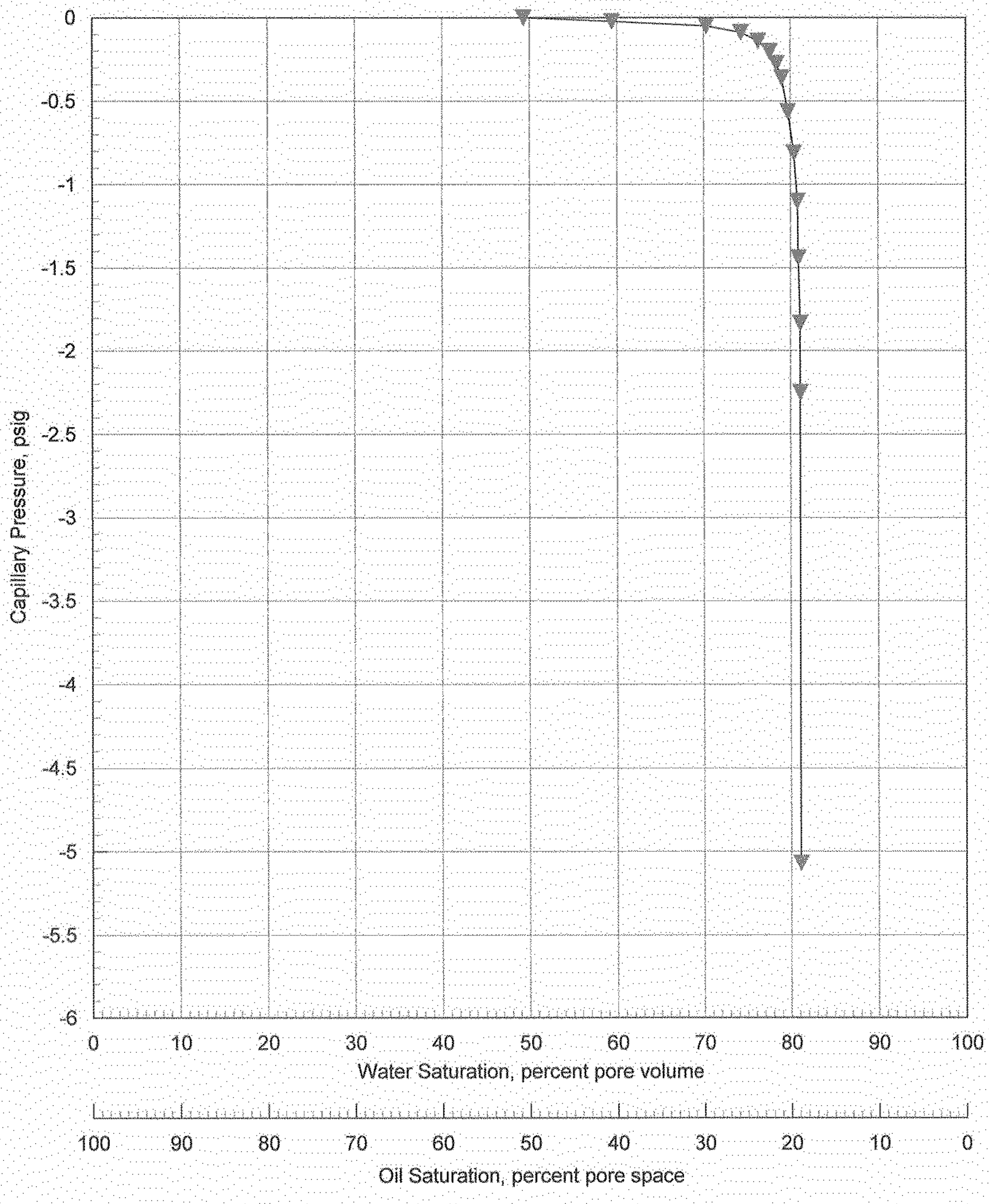
PTS Laboratories

Earth Tech, Inc.
File No.: 38167

CAPILLARY PRESSURE
Centrifugal Method
Oil/Water Imbibition (Water Displacing Oil) - ASTM D6836

Project Name: Montrose-Torrance
Project Number: N/A

Sample ID: 2DSB-1-79
Depth, ft.: 79



Appendix C

C-1 Estimated MCB Mass in the Unsaturated Zone from Ground Surface to 25 feet bgs
C-2 Estimated MCB Mass in the Unsaturated Zone Between 25 and 60 feet bgs

Table C-1
Estimated MCB Mass in the Unsaturated Zone from Ground Surface to 25 Feet bgs
Montrose Superfund Site

Soil Boring ID		MCB Conc (mg/kg) at Sample Depths Between Ground Surface and 25 Feet bgs											Average MCB Conc per Boring (mg/kg)
Area 1 - MCB >1,000 mg/kg; 28,049 Square Feet													
C15	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	13	9	1,200	5,300	13,000	16,000	-	-	-	-	-	5,920
14D	Depth (ft bgs)	3.5	5	6.5	8	9.5	11	13.5	-	-	-	-	
	Conc (mg/kg)	3	6.4	910	540	7,100	14,000	9,000	-	-	-	-	4,508
EW-1	Depth (ft bgs)	10	15	20	-	-	-	-	-	-	-	-	
	Conc (mg/kg)	6.3	14	880				-	-	-	-	-	300
S305	Depth (ft bgs)	7.8	8.3	14.6	24.3	-	-	-	-	-	-	-	
	Conc (mg/kg)	1,500	3	6,900	2,800		-	-	-	-	-	-	2,801
S301	Depth (ft bgs)	9.2	19.7	-	-	-	-	-	-	-	-	-	
	Conc (mg/kg)	190	1,900	-	-	-	-	-	-	-	-	-	1,045
S304	Depth (ft bgs)	9.2	19.7	-	-	-		-	-	-	-	-	
	Conc (mg/kg)	8,200	830	-	-	-		-	-	-	-	-	4,515
C14	Depth (ft bgs)	1	3	5	7	10	15	-	-	-	-	-	
	Conc (mg/kg)	1.2	68	310	780	200	430	-	-	-	-	-	298
Area 1 - Average MCB Conc													2,770
Area 2 - MCB >1,000 mg/kg; 2,733 Square Feet													
24D	Depth (ft bgs)	5	6	6.5	8	9.5	12.5	14.5	16	16.5	18	19.5	
	Conc (mg/kg)	20	0.16	0.26	2.7	1.1	12,000	3,300	2,800	2,900	4,500	29	2,323
Area 3 - MCB >1,000 mg/kg; 1,203 Square Feet													
C33	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	0.027	1,200	1,200	1,800	1,400	180	-	-	-	-	-	963
Area 4 - MCB >100 mg/kg but <1,000 mg/kg; 46,333 Square Feet													
C9	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	2.4	160	28	0.015	0.043	1.4	-	-	-	-	-	32
C26	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	0.31	1.3	2	17	0.28	120	-	-	-	-	-	23
C30	Depth (ft bgs)	1	3	5	7	10	20	25	-	-	-	-	
	Conc (mg/kg)	0.0016	0.094	3.2	0.13	0.15	55	170	-	-	-	-	33
C32	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	1	6.2	410	36	4.8	140	-	-	-	-	-	100
S101	Depth (ft bgs)	23						-	-	-	-	-	
	Conc (mg/kg)	190						-	-	-	-	-	190
S201	Depth (ft bgs)	16	16.5	17	17	20.5		-	-	-	-	-	
	Conc (mg/kg)	310	200	0.65	64	120		-	-	-	-	-	139
S303	Depth (ft bgs)	8.4	18.4					-	-	-	-	-	
	Conc (mg/kg)	11	130					-	-	-	-	-	71
15D	Depth (ft bgs)	1.5	2	3.5	4.5	8	9.5	-	-	-	-	-	
	Conc (mg/kg)	4	360	15	1.8	0.02	0.02	-	-	-	-	-	63
Area 4 - Average MCB Conc													81
Area 5 - MCB >100 mg/kg but <1,000 mg/kg; 4,392 Square Feet													
C46	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	3.7	320	0.063	0.15	0.087	1	-	-	-	-	-	54
C52	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	0.26	110	16	1.7	0.053	1.4	-	-	-	-	-	22
Area 5 - Average MCB Conc													38
Area 6 - MCB >100 mg/kg but <1,000 mg/kg; 940 Square Feet													
C64	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	94	86	190	730	900	5.4	-	-	-	-	-	334
Area 7 - MCB >10 mg/kg but <100 mg/kg; 51,212 Square Feet													
C22	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	0.12	59	0.04	0.56	1.2	5.7	-	-	-	-	-	11
C31	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	0.091	5.4	13	0.15	0.073	34	-	-	-	-	-	9
C41	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	37	8.7	0.92	1.2	3.8	2.6	-	-	-	-	-	9
C45	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	9.8	33	18	8.1	1	7.3	-	-	-	-	-	13
C51	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	0.2	20	0.35	4.2	0.31	3.1	-	-	-	-	-	5
C55	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	0.0036	6.6	0.086	14	0.00074	0.00095	-	-	-	-	-	3
C59	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	4.2	15	4	9.5	5.5	12	-	-	-	-	-	8
C2	Depth (ft bgs)	1	3	5	7	10	20	-	-	-	-	-	
	Conc (mg/kg)	30	0.0016	0	0	0.97	0	-	-	-	-	-	5
25D	Depth (ft bgs)	1	2	2.5	4.5	5	7.5	9.5	11	-	-	-	
	Conc (mg/kg)	0.08	29	13	0.014	1.6	0	0	0	-	-	-	5
MW002	Depth (ft bgs)	6.5	11.5	17	22			-	-	-	-	-	
	Conc (mg/kg)	70	0	4	6			-	-	-	-	-	20
S302E,F	Depth (ft bgs)	8.3	8.8	9.1	21.8			-	-	-	-	-	
	Conc (mg/kg)	19	4.9	1.3	15			-	-	-	-	-	10
35D	Depth (ft bgs)	1.5	2	2.5	3.5	4.5	6	6.5	9.5	-	-	-	
	Conc (mg/kg)	1.1	0.018	2.1	22	1.5	0.1	0	0	-	-	-	3
Area 7 - Average MCB Conc													9

Notes:
bgs = below ground surface
ft = feet
sq ft = square feet
g/cc = grams per cubic centimeter
lbs = pounds
mg/kg = milligrams per kilogram
MCB = Monochlorobenzene
Conc = concentration

	Area	Avg MCB Conc (mg/kg)	Area (sq ft)	Thickness (ft)	Soil Density (g/cc)	Estimated MCB Mass (lbs)
	Area 1	2,770	28,049	25	1.66	201,266
	Area 2	2,323	2,733	25	1.66	16,448
	Area 3	963	1,203	25	1.66	3,002
	Area 4	81	46,333	25	1.66	9,763
	Area 5	38	4,392	25	1.66	431
	Area 6	334	940	25	1.66	814
	Area 7	9	51,212	25	1.66	1,131
DNAPL →	SSB-4	14,000	3,000	1	1.66	4,352

Total Estimated MCB Mass 0-25 Feet bgs (lbs) = 237,208

Table C-2
Estimated MCB Mass in the Unsaturated Zone Between 25 and 60 Feet bgs
Montrose Superfund Site

Soil Boring ID	MCB Conc (mg/kg) at Sample Depths Between 25 and 60 Feet bgs								Average MCB Conc per Boring (mg/kg)
Area 1 - MCB >100 mg/kg; 41,544 Square Feet									
C15	Depth (ft bgs)	30	40	50	60	-	-	-	
	Conc (mg/kg)	4,400	4,700	21	0.18	-	-	-	2,280
EW-1	Depth (ft bgs)	30	35	40	50	55	60	-	
	Conc (mg/kg)	440	3,300	1,000	3,800	200	16	-	1,459
S305	Depth (ft bgs)	34.3	37	44.3	44.8	54.3	-	-	
	Conc (mg/kg)	4,700	2,700	5,600	7,700	6,000	-	-	5,340
S301	Depth (ft bgs)	28	39.2	39.7	50.3	-	-	-	
	Conc (mg/kg)	55	1,400	170	24	-	-	-	412
S304	Depth (ft bgs)	29.6	30.1	38.3	44.1	51.7	58.8	-	
	Conc (mg/kg)	3,700	3,800	1,900	4,400	4.5	1.5	-	2,301
S204	Depth (ft bgs)	26.3	30.5	42	50	50.5	51	60	
	Conc (mg/kg)	1	0.5	4	3.2	1	0.2	2,400	344
S201	Depth (ft bgs)	30.5	35.5	46.5	51	-	-	-	
	Conc (mg/kg)	16	13	460	4,400	-	-	-	1,222
S101	Depth (ft bgs)	27	32	37	42	47	52	-	
	Conc (mg/kg)	1,200	3,400	3,500	3,800	1,800	2,900	-	2,767
MW002	Depth (ft bgs)	27	32	37	42	47	52	57	
	Conc (mg/kg)	160	23	14	1	96	420	38	107
Area 1 - Average MCB Concentration									1,804
Area 2 - MCB >100 mg/kg; 680 Square Feet									
S302F	Depth (ft bgs)	31.3	39.2	39.7	49.2	59.2	-	-	
	Conc (mg/kg)	2	1.6	6.7	52	3,200	-	-	652
Area 3 - MCB >10 mg/kg but <100 mg/kg; 33,083 Square Feet									
C9	Depth (ft bgs)	30	40	50	60	-	-	-	
	Conc (mg/kg)	1.5	6.5	0.27	13	-	-	-	5
C26	Depth (ft bgs)	30	40	50	60	-	-	-	
	Conc (mg/kg)	16	-	-	-	-	-	-	16
C30	Depth (ft bgs)	30	40	50	60	-	-	-	
	Conc (mg/kg)	3.2	20	0.23	0.39	-	-	-	6
C31	Depth (ft bgs)	30	40	50	60	-	-	-	
	Conc (mg/kg)	9.3	0.22	1.1	1	-	-	-	3
C32	Depth (ft bgs)	30	40	50	60	-	-	-	
	Conc (mg/kg)	1.3	2.4	21	36	-	-	-	15
C33	Depth (ft bgs)	30	40	50	60	-	-	-	
	Conc (mg/kg)	2	1.7	0.18	9.8	-	-	-	3
Area 3 - Average MCB Concentration									8
Area 4 - MCB >10 mg/kg but <100 mg/kg; 1,259 Square Feet									
C50	Depth (ft bgs)	30	40	50	60	-	-	-	
	Conc (mg/kg)	0.24	0.014	0.62	11	-	-	-	3
Area 5 - MCB >10 mg/kg but <100 mg/kg; 3,238 Square Feet									
C59	Depth (ft bgs)	30	40	50	60	-	-	-	
	Conc (mg/kg)	0.068	3.5	0.087	10	-	-	-	3

Notes:
bgs = below ground surface
ft = feet
sq ft = square feet
g/cc = grams per cubic centimeter
lbs = pounds
mg/kg = milligrams per kilogram
MCB = Monochlorobenzene
Conc = concentration

	Area	Avg MCB Conc (mg/kg)	Area (sq ft)	Thickness (ft)	Soil Density (g/cc)	Estimated MCB Mass (lbs)
	Area 1	1,804	41,544	35	1.52	248,864
	Area 2	652	680	35	1.52	1,473
	Area 3	8	33,083	35	1.52	893
	Area 4	3	1,259	35	1.52	12
	Area 5	3	3,238	35	1.52	37
DNAPL →	PSB-5	70,000	3,000	0.5	1.52	9,963

Total Estimated MCB Mass 25-60 Feet bgs (lbs) =	261,243

Appendix D

D-1 DNAPL Characterization as Definite or Possible in Saturated Upper Bellflower Aquitard

Table D-1
DNAPL Characterization as Definite or Possible in Saturated UBA
Montrose Superfund Site

DNAPL Presence Line of Evidence				Primary			Secondary												DNAPL Occurrence			Basis For Definition	Consultant
Boring ID	Sample Date	Depth Interval Top	Depth Interval Bottom	Visual Observation	FLUTe Stain	Soil Sample	MCB (mg/kg)	2,4'-DDD (mg/kg)	2,4'-DDE (mg/kg)	2,4'-DDT (mg/kg)	4,4'-DDD (mg/kg)	4,4'-DDE (mg/kg)	4,4'-DDT (mg/kg)	Total DDT (mg/kg)	DNAPL Conc. (mg/kg)	FID (ppmv)	PID (ppmv)	Boring Log Notes[1]	Definite	Possible	Not Present		
	5/6/2003	60.00	60.10	N	N	N	--	--	--	--	--	--	--	--	--	33	11		N	N	Y		H+A
	5/6/2003	65.50	65.60	N	N	N	--	--	--	--	--	--	--	--	--	175	66		N	N	Y		H+A
	5/6/2003	68.00	68.10	N	N	N	--	--	--	--	--	--	--	--	--	111	45		N	N	Y		H+A
	5/6/2003	70.00	70.10	N	N	N	--	--	--	--	--	--	--	--	--	43	25		N	N	Y		H+A
	5/6/2003	71.50	71.60	N	N	N	--	--	--	--	--	--	--	--	--	420	120		N	N	Y		H+A
	5/6/2003	74.00	74.10	N	N	N	--	--	--	--	--	--	--	--	--	1,700	320		N	Y	N	Headspace	H+A
	5/6/2003	75.00	75.10	N	N	N	--	--	--	--	--	--	--	--	--	470	170		N	N	Y		H+A
DP-1	5/6/2003	79.00	79.10	N	N	Y	310	<51	<51	<51	<51	<51	110	110	420	2,115	310		N	Y	N	Lab, Headspace,	H+A
	5/6/2003	79.50	79.60	N	N	N	--	--	--	--	--	--	--	--	--	1,420	340		N	N	Y		H+A
	5/6/2003	82.00	82.10	N	N	N	--	--	--	--	--	--	--	--	--	>2000	350		N	Y	N	Headspace	H+A
	5/6/2003	83.50	83.60	N	N	N	--	--	--	--	--	--	--	--	--	1,020	180		N	N	Y		H+A
	5/6/2003	85.00	85.10	N	N	Y	480	<71	<71	<71	<71	<71	170	170	650	--	--		Y'	N	N	Lab	H+A
	5/6/2003	86.00	86.10	N	N	N	--	--	--	--	--	--	--	--	--	7,000	579		N	Y	N	Headspace	H+A
	5/6/2003	88.00	88.10	N	N	N	--	--	--	--	--	--	--	--	--	1,400	365		N	N	Y		H+A
	5/6/2003	90.00	90.10	N	N	N	--	--	--	--	--	--	--	--	--	1,870	370		N	Y	N	Headspace	H+A
	5/6/2003	65.00	65.10	N	N	N	--	--	--	--	--	--	--	--	--	630	230		N	N	Y		H+A
	5/6/2003	67.00	67.10	N	N	N	--	--	--	--	--	--	--	--	--	1,380	340		N	N	Y		H+A
	5/6/2003	69.00	69.10	N	N	N	--	--	--	--	--	--	--	--	--	387	115		N	N	Y		H+A
	5/6/2003	72.00	72.10	N	N	N	--	--	--	--	--	--	--	--	--	390	120		N	N	Y		H+A
	5/6/2003	73.00	73.10	N	N	N	--	--	--	--	--	--	--	--	--	1,130	290		N	N	Y		H+A
	5/6/2003	75.00	75.10	N	N	N	--	--	--	--	--	--	--	--	--	470	170		N	N	Y		H+A
	5/6/2003	77.00	77.10	N	N	N	--	--	--	--	--	--	--	--	--	1,330	327		N	N	Y		H+A
DP-2	5/6/2003	77.50	77.60	N	N	N	--	--	--	--	--	--	--	--	--	325	186		N	N	Y		H+A
	5/6/2003	79.00	79.10	N	N	Y	210	<27	<27	<27	<27	<27	42	42	252	2,002	330		N	Y	N	Headspace	H+A
	5/6/2003	85.00	85.10	N	N	N	--	--	--	--	--	--	--	--	--	220	110		N	N	Y		H+A
	5/6/2003	87.00	87.10	N	N	N	--	--	--	--	--	--	--	--	--	315	131		N	N	Y		H+A
	5/6/2003	88.00	88.10	N	N	N	--	--	--	--	--	--	--	--	--	1,090	288		N	N	Y		H+A
	5/6/2003	88.50	88.60	N	N	N	--	--	--	--	--	--	--	--	--	1,278	350		N	N	Y		H+A
	5/7/2003	89.00	89.10	N	N	Y	130	<29	<29	<29	<29	<29	110	110	240	--	--		N	Y	N	Lab	H+A
	5/7/2003	60.00	60.10	N	N	N	--	--	--	--	--	--	--	--	--	18	10		N	N	Y		H+A
	5/7/2003	67.00	67.10	N	N	N	--	--	--	--	--	--	--	--	--	380	126		N	N	Y		H+A
	5/7/2003	70.50	70.60	N	N	N	--	--	--	--	--	--	--	--	--	1,882	431		N	Y	N	Headspace	H+A
	5/7/2003	71.00	71.60	N	N	Y	<28	<28	<28	<28	<28	<28	<28	<28	<28	201	99		N	N	Y		H+A
	5/7/2003	73.00	73.10	N	N	N	--	--	--	--	--	--	--	--	--	309	139		N	N	Y		H+A
DP-3	5/7/2003	75.50	75.60	N	N	N	--	--	--	--	--	--	--	--	--	640	220		N	N	Y		H+A
	5/7/2003	76.50	76.60	N	N	N	--	--	--	--	--	--	--	--	--	7,905	860		N	Y	N	Headspace	H+A
	5/7/2003	78.80	78.90	Y	Y	Y	13,000	<3,700	<3,700	<3,700	<3,700	<3,700	8,300	8,300	21,300	30,000	880	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
	5/7/2003	81.00	81.10	N	N	N	--	--	--	--	--	--	--	--	--	148	78		N	N	Y		H+A
	5/7/2003	81.70	81.80	N	Y	N	--	--	--	--	--	--	--	--	--	829	341		Y	N	N	FLUTe	H+A
	5/7/2003	86.00	86.10	N	N	N	--	--	--	--	--	--	--	--	--	222	115		N	N	Y		H+A
	5/8/2003	60.50	60.60	N	N	N	--	--	--	--	--	--	--	--	--	9	3		N	N	Y		H+A
	5/8/2003	65.00	65.10	N	N	N	--	--	--	--	--	--	--	--	--	1,040	350		N	N	Y		H+A
	5/8/2003	66.00	66.10	N	N	N	--	--	--	--	--	--	--	--	--	12	11		N	N	Y		H+A
	5/8/2003	68.00	68.10	N	N	N	--	--	--	--	--	--	--	--	--	2,970	680		N	Y	N	Headspace	H+A
	5/8/2003	73.20	73.30	N	N	N	--	--	--	--	--	--	--	--	--	2,588	660		N	Y	N	Headspace	H+A
DP-4	5/8/2003	75.00	75.10	N	N	N	--	--	--	--	--	--	--	--	--	143	89		N	N	Y		H+A
	5/8/2003	76.70	76.80	N	N	Y	30	<28	<28	<28	<28	<28	<28	<28	30	231	140		N	N	Y		H+A
	5/8/2003	81.00	81.10	N	N	N	--	--	--	--	--	--	--	--	--	1,498	529		N	N	Y		H+A
	5/8/2003	84.00	84.10	N	N	N	--	--	--	--	--	--	--	--	--	593	287		N	N	Y		H+A
	5/8/2003	86.70	86.80	N	N	Y	45	<28	<28	<28	<28	<28	<28	<28	45	231	147		N	N	Y		H+A
	5/8/2003	88.00	88.10	N	N	N	--	--	--	--	--	--	--	--	--	993	347		N	N	Y		H+A
	5/8/2003	62.00	62.10	N	N	N	--	--	--	--	--	--	--	--	--	28	11		N	N	Y		H+A
	5/8/2003	65.50	65.60	N	N	N	--	--	--	--	--	--	--	--	--	19	4		N	N	Y		H+A
	5/8/2003	68.00	68.10	N	N	N	--	--	--	--	--	--	--	--	--	36	13		N	N	Y		H+A
	5/8/2003	69.50	69.60	N	N	N	--	--	--	--	--	--	--	--	--	46	18		N	N	Y		H+A
	5/8/2003	72.60	72.70	N	N	Y	95	<34	<34	<34	<34	43	85	128	223	27	10		N	Y	N	Lab	H+A
	5/8/2003	73.50	73.60	N	N	N	--	--	--	--	--	--	--	--	--	83	45		N	N	Y		H+A
DP-5	5/8/2003	77.00	77.10	N	N	N	--	--	--	--	--	--	--	--	--	410	157		N	N	Y		H+A
	5/8/2003	78.00	78.10	N	N	N	--	--	--	--	--	--	--	--	--	259	136		N	N	Y		H+A
	5/8/2003	80.00	80.10	N	N	N	--	--	--	--	--	--	--	--	--	182	101		N	N	Y		H+A
	5/8/2003	83.50	83.60	N	N	N	--	--	--	--	--	--	--	--	--	73	36		N	N	Y		H+A
	5/8/2003	89.60	89.70	Y	Y	Y	3,400	<1,400	<1,400	<1,400	<1,400	<1,400	2,400	2,400	5,800	2,453	757	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab.	H+A
	5/8/2003	90.50	90.60	N	N	N	--	--	--	--	--	--	--	--	--	623	297		N	N	Y		H+A

BOE-C6-0060012

Table D-1
DNAPL Characterization as Definite or Possible in Saturated UBA
Montrose Superfund Site

DNAPL Presence Line of Evidence				Primary			Secondary												DNAPL Occurrence			Basis For Definition	Consultant
Boring ID	Sample Date	Depth Interval Top	Depth Interval Bottom	Visual Observation	FLUTe Stain	Soil Sample	MCB (mg/kg)	2,4'-DDD (mg/kg)	2,4'-DDE (mg/kg)	2,4'-DDT (mg/kg)	4,4'-DDD (mg/kg)	4,4'-DDE (mg/kg)	4,4'-DDT (mg/kg)	Total DDT (mg/kg)	DNAPL Conc. (mg/kg)	FID (ppmv)	PID (ppmv)	Boring Log Notes[1]	Definite	Possible	Not Present		
DP-7	5/9/2003	63.50	63.60	N	N	N	--	--	--	--	--	--	--	--	--	31	21		N	N	Y		H+A
	5/9/2003	65.50	65.60	N	N	N	--	--	--	--	--	--	--	--	--	23	14		N	N	Y		H+A
	5/9/2003	68.50	68.60	N	N	N	--	--	--	--	--	--	--	--	--	136	82		N	N	Y		H+A
	5/9/2003	71.90	72.00	N	N	Y	<31	<31	<31	<31	<31	<31	<31	<31	<31	244	142		N	N	Y		H+A
	5/9/2003	76.50	76.60	N	N	N	--	--	--	--	--	--	--	--	--	242	135		N	N	Y		H+A
	5/9/2003	77.50	77.60	N	N	N	--	--	--	--	--	--	--	--	--	111	61		N	N	Y		H+A
	5/9/2003	80.25	80.35	N	N	N	--	--	--	--	--	--	--	--	--	121	76		N	N	Y		H+A
	5/9/2003	89.30	89.50	Y	Y	Y	16,000	<3,900	<3,900	<3,900	<3,900	<3,900	12,000	12,000	28,000	30,000	1,190	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
	5/9/2003	89.60	89.70	N	N	N	--	--	--	--	--	--	--	--	--	15,000	115		Y	N	N	Headspace	H+A
	5/9/2003	89.80	89.90	N	N	N	--	--	--	--	--	--	--	--	--	247	518		N	N	Y		H+A
	5/9/2003	94.90	95.00	N	N	Y	95	<23	<23	<23	<23	<23	42	42	137	610	280		N	N	Y		H+A
	5/9/2003	96.50	96.60	N	N	N	--	--	--	--	--	--	--	--	--	191	74		N	N	Y		H+A
DP-8	5/12/2003	60.50	60.60	N	N	N	--	--	--	--	--	--	--	--	--	110	88		N	N	Y		H+A
	5/12/2003	64.70	64.80	N	N	N	--	--	--	--	--	--	--	--	--	3,450	818		N	Y	N	Headspace	H+A
	5/12/2003	66.00	66.10	N	N	N	--	--	--	--	--	--	--	--	--	796	398		N	N	Y		H+A
	5/12/2003	67.00	67.10	N	N	N	--	--	--	--	--	--	--	--	--	3,510	744		N	Y	N	Headspace	H+A
	5/12/2003	69.25	69.35	N	N	N	--	--	--	--	--	--	--	--	--	250	152		N	N	Y		H+A
	5/12/2003	72.00	72.10	N	N	N	--	--	--	--	--	--	--	--	--	6,300	861		N	Y	N	Headspace	H+A
	5/12/2003	74.00	74.10	N	N	N	--	--	--	--	--	--	--	--	--	570	212		N	N	Y		H+A
	5/12/2003	75.50	75.60	N	N	N	--	--	--	--	--	--	--	--	--	230	114		N	N	Y		H+A
	5/12/2003	76.75	76.85	N	N	N	--	--	--	--	--	--	--	--	--	538	245		N	N	Y		H+A
	5/12/2003	79.90	80.00	N	N	Y	100	<24	<24	<24	<24	<24	<24	<24	100	216	61		N	N	Y		H+A
	5/12/2003	85.00	85.10	N	N	N	--	--	--	--	--	--	--	--	--	660	304		N	N	Y		H+A
	5/12/2003	88.00	88.10	N	N	N	--	--	--	--	--	--	--	--	--	224	118		N	N	Y		H+A
	5/12/2003	89.10	89.20	N	N	Y	<27	<27	<27	<27	<27	<27	<27	<27	<27	83	34		N	N	Y		H+A
DP-12	5/14/2003	60.50	60.60	N	N	N	--	--	--	--	--	--	--	--		12,700	1,590		Y	N	N	Headspace	H+A
	5/14/2003	64.50	64.60	N	N	N	--	--	--	--	--	--	--	--		799	462		N	N	Y		H+A
	5/14/2003	68.50	68.60	N	N	N	--	--	--	--	--	--	--	--		789	445		N	N	Y		H+A
	5/14/2003	70.00	70.10	N	N	N	--	--	--	--	--	--	--	--		324	210		N	N	Y		H+A
	5/14/2003	72.00	72.10	N	N	Y	40	<24	<24	<24	<24	<24	<24	<24	40	712	317		N	N	Y		H+A
	5/14/2003	74.00	74.10	N	N	N	--	--	--	--	--	--	--	--	--	410	227		N	N	Y		H+A
	5/14/2003	77.00	77.10	N	N	N	--	--	--	--	--	--	--	--	--	33	19		N	N	Y		H+A
	5/14/2003	79.00	79.10	N	N	N	--	--	--	--	--	--	--	--	--	93	58		N	N	Y		H+A
	5/14/2003	81.00	81.10	N	N	Y	550	<130	<130	130	<130	<130	420	550	1,100	2,310	941		N	Y	N	Lab, Headspace	H+A
	5/14/2003	85.50	85.60	N	N	N	--	--	--	--	--	--	--	--	--	729	427		N	N	Y		H+A
	5/14/2003	99.00	99.10	N	N	N	--	--	--	--	--	--	--	--	--	979	445		N	N	Y		H+A
PSB-1	10/7/2003	62.50	62.60	N	N	N	--	--	--	--	--	--	--	--	--	52	37		N	N	Y		H+A
	10/7/2003	63.50	63.60	N	N	N	--	--	--	--	--	--	--	--	--	167	92		N	N	Y		H+A
	10/7/2003	67.50	67.60	N	N	N	--	--	--	--	--	--	--	--	--	178	254		N	N	Y		H+A
	10/7/2003	71.50	71.60	N	N	N	--	--	--	--	--	--	--	--	--	331	118		N	N	Y		H+A
	10/7/2003	74.00	74.10	N	N	N	--	--	--	--	--	--	--	--	--	276	109		N	N	Y		H+A
	10/7/2003	76.40	76.50	N	N	Y	1,700	<510	<510	<510	<510	<510	1,900	1,900	3,600	16,500	1,768	Very Strong Odor	Y	N	N	Lab, Headspace	H+A
	10/7/2003	77.50	77.60	N	N	N	--	--	--	--	--	--	--	--	--	18,000	1,650		Y	N	N	Headspace	H+A
	10/7/2003	81.00	81.20	Y	Y	Y	2,400	<580	<580	620	<580	<580	2,500	3,120	5,520	9,760	1,461	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab	H+A
	10/7/2003	82.70	82.80	N	N	N	--	--	--	--	--	--	--	--	--	730	382		N	N	Y		H+A
	10/7/2003	89.50	89.70	N	N	N	--	--	--	--	--	--	--	--	--	27,000	1,688		Y	N	N	Headspace	H+A
	10/7/2003	93.50	93.60	N	N	N	--	--	--	--	--	--	--	--	--	1,272	655		N	N	Y		H+A
PSB-2	10/8/2003	62.00	62.10	N	N	N	--	--	--	--	--	--	--	--	--	163	147		N	N	Y		H+A
	10/8/2003	68.00	68.10	N	N	N	--	--	--	--	--	--	--	--	--	15	18		N	N	Y		H+A
	10/8/2003	75.00	75.10	N	Y	Y	7,100	<1,500	<1,500	2,100	<1,500	<1,500	7,700	9,800	16,900	21,000	2,670	Very Strong Odor	Y	N	N	FLUTe, Lab, Headspace	H+A
	10/8/2003	75.50	75.80	N	Y	N	--	--	--	--	--	--	--	--	--	13,100	2,223		Y	N	N	FLUTe, Headspace	H+A
	10/8/2003	83.50	83.60	N	N	N	--	--	--	--	--	--	--	--	--	270	252		N	N	Y		H+A
	10/8/2003	87.50	87.60	N	N	N	--	--	--	--	--	--	--	--	--	393	489		N	N	Y		H+A
	10/8/2003	92.00	92.10	N	N	Y	43	<28	<28	<28	<28	<28	<28	<28	43	525	661	Odor	N	N	Y		H+A
PSB-3	10/9/2003	63.50	63.60	N	N	N	--	--	--	--	--	--	--	--	--	178	140		N	N	Y		H+A
	10/9/2003	69.00	69.10	N	N	N	--	--	--	--	--	--	--	--	--	17	16		N	N	Y		H+A
	10/9/2003	75.50	75.60	Y	Y	Y	3,000	<630	<630	650	<630	<630	2,500	3,150	6,150	2,135	1,170	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab	H+A
	10/9/2003	79.00	79.20	Y	Y	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	FLUTe, Visual	H+A
	10/9/2003	79.40	79.50	Y	Y	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	FLUTe, Visual	H+A
	10/9/2003	79.90	80.00	Y	Y	Y	480	<120	<120	<120	<120	<120	250	250	730	19,100	2,111	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Headspace	H+A
	10/9/2003	88.00	88.10	N	N	N	--	--	--	--	--	--	--	--	--	574	420		N	N	Y		H+A
PSB-4	10/10/2003	64.00	64.10	N	N	N	--	--	--	--	--	--	--	--	--	19,500	2,251		Y	N	N	Headspace	H+A
	10/10/2003	69.50	69.60	N	N	N	--	--	--	--	--	--	--	--	--	151	179		N	N	Y		H+A
	10/10/2003	75.00	75.10	N	N	Y	150	<140	<140	200	<140	<140	680	880	1,030	602	567	Odor	N	Y	N	Lab	H+A
	10/10/2003	79.00	79.10	N	N	N	--	--	--	--	--	--	--	--	--	319	324		N	N	Y		H+A
	10/10/2003	84.25	84.35	N	N	N	--	--	--	--	--	--	--	--	--	138	165		N	N	Y		H+A
	10/10/2003	88.00	88.10	Y	Y	Y	45,000	<7,000	<7,000	9,400	<7,000	<7,000	28,000	37,400	82,400	24,400	2,459	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
	10/10/2003	90.50	90.70	Y	Y	Y	1,600	<500	<500	<500	<500	<500	920	920	2,520	23,100	2,369	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A

Table D-1
DNAPL Characterization as Definite or Possible in Saturated UBA
Montrose Superfund Site

DNAPL Presence Line of Evidence				Primary			Secondary												DNAPL Occurrence			Basis For Definition	Consultant
		Depth Interval		Visual	FLUTe	Soil	MCB	2,4'-DDD	2,4'-DDE	2,4'-DDT	4,4'-DDD	4,4'-DDE	4,4'-DDT	Total DDT	DNAPL Conc.	FID	PID	Boring Log			Not		
Boring ID	Sample Date	Top	Bottom	Observation	Stain	Sample	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(ppmv)	(ppmv)	Notes[1]	Definite	Possible	Present		
PSB-5	10/13/2003	63.00	63.10	N	N	N	--	--	--	--	--	--	--	--	--	610	241		N	N	Y		H+A
	10/13/2003	68.00	68.10	N	N	N	--	--	--	--	--	--	--	--	--	300	176		N	N	Y		H+A
	10/13/2003	74.00	74.10	N	Y	N	--	--	--	--	--	--	--	--	--	1,157	307		Y	N	N	FLUTe	H+A
	10/13/2003	79.00	79.10	N	N	N	--	--	--	--	--	--	--	--	--	564	241		N	N	Y		H+A
	10/13/2003	84.00	84.10	N	N	N	--	--	--	--	--	--	--	--	--	245	180		N	N	Y		H+A
	10/13/2003	88.50	88.60	N	N	N	--	--	--	--	--	--	--	--	--	301	155		N	N	Y		H+A
	10/13/2003	90.00	91.20	Y	Y	Y	14,000	<2,900	<2,900	4,100	<2,900	<2,900	12,000	16,100	30,100	22,200	1,965	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
PSB-6	10/14/2008	62.00	62.10	N	N	N	--	--	--	--	--	--	--	--	--	42	69		N	N	Y		H+A
	10/14/2008	65.00	65.10	N	N	N	--	--	--	--	--	--	--	--	--	142	101		N	N	Y		H+A
	10/14/2008	68.00	68.10	N	N	N	--	--	--	--	--	--	--	--	--	90	40		N	N	Y		H+A
	10/14/2008	74.50	74.60	N	N	N	--	--	--	--	--	--	--	--	--	85	42		N	N	Y		H+A
	10/14/2008	78.50	78.60	N	N	N	--	--	--	--	--	--	--	--	--	262	125		N	N	Y		H+A
	10/14/2008	93.50	93.60	N	N	N	--	--	--	--	--	--	--	--	--	89	32		N	N	Y		H+A
	10/14/2008	84.80	84.90	N	N	Y	<31	<31	<31	<31	<31	<31	<31	<31	<31	90	42		N	N	Y		H+A
	10/14/2008	90.40	90.70	Y	Y	Y	27,000	<6,800	<6,800	8,100	<6,800	<6,800	19,000	27,100	54,100	11,000	2,000	Oily sheen, very strong odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
	10/14/2008	93.50	93.60	N	N	N	--	--	--	--	--	--	--	--	--	89	32		N	N	Y		H+A
PSB-9	10/17/2003	62.50	62.60	N	N	N	--	--	--	--	--	--	--	--	--	215	175		N	N	Y		H+A
	10/17/2003	65.50	65.60	N	N	N	--	--	--	--	--	--	--	--	--	300	129		N	N	Y		H+A
	10/17/2003	75.50	75.60	N	N	N	--	--	--	--	--	--	--	--	--	110	38		N	N	Y		H+A
	10/17/2003	81.00	81.10	N	N	N	--	--	--	--	--	--	--	--	--	0	9		N	N	Y		H+A
	10/17/2003	82.00	82.10	N	N	N	--	--	--	--	--	--	--	--	--	44	10		N	N	Y		H+A
	10/17/2003	85.50	85.60	N	N	Y	<34	<34	<34	<34	<34	<34	<34	<34	<34	44	10		N	N	Y		H+A
	10/17/2003	92.20	92.60	Y	Y	Y	2,000	<280	<280	390	<280	<280	1400	1,790	3,790	319	277		Y	N	N	FLUTe, Visual, Lab	H+A
	10/17/2003	93.20	93.40	Y	Y	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	FLUTe, Visual	H+A
	10/17/2003	94.30	94.40	Y	Y	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	FLUTe, Visual	H+A
PSB-10	10/28/2003	60.50	60.60	N	N	Y	<30	<30	<30	<30	<30	<30	<30	<30	<30	133	252		N	N	Y		H+A
	10/28/2003	68.00	68.10	N	N	N	--	--	--	--	--	--	--	--	--	59	29		N	N	Y		H+A
	10/28/2003	72.80	72.90	N	N	N	--	--	--	--	--	--	--	--	--	250	148		N	N	Y		H+A
	10/28/2003	77.00	77.10	N	N	N	--	--	--	--	--	--	--	--	--	1,948	450		N	Y	N	Headspace	H+A
	10/28/2003	83.90	84.00	N	N	N	--	--	--	--	--	--	--	--	--	200	396		N	N	Y		H+A
	10/28/2003	89.50	89.60	N	N	Y	44	<33	<33	<33	<33	<33	<33	<33	44	104	61		N	N	Y		H+A
PSB-11	10/29/2003	60.00	60.10	N	N	N	--	--	--	--	--	--	--	--	--	543	240		N	N	Y		H+A
	10/29/2003	64.90	65.00	N	N	N	--	--	--	--	--	--	--	--	--	277	144		N	N	Y		H+A
	10/29/2003	69.90	70.00	N	N	N	--	--	--	--	--	--	--	--	--	168	81		N	N	Y		H+A
	10/29/2003	74.40	74.50	N	N	Y	3,200	<2,000	<2,000	2,300	<2,000	<2,000	6,400	8,700	11,900	476	192		Y	N	N	Lab	H+A
	10/29/2003	77.90	78.00	N	N	N	--	--	--	--	--	--	--	--	--	3,010	705		N	Y	N	Headspace	H+A
	10/29/2003	81.60	81.70	N	N	Y	47	<40	<40	<40	<40	<40	<40	<40	47	--	--		N	N	Y		H+A
	10/29/2003	86.50	86.60	N	N	N	--	--	--	--	--	--	--	--	--	7,584	1,084		N	Y	N	Headspace	H+A
	10/29/2003	90.00	90.10	N	N	N	--	--	--	--	--	--	--	--	--	485	212		N	N	Y		H+A
PSB-12	10/30/2003	61.80	61.90	N	N	N	--	--	--	--	--	--	--	--	--	404	419		N	N	Y		H+A
	10/30/2003	65.20	65.30	N	N	Y	<40	<40	<40	<40	<40	<40	<40	<40	<40	569	557		N	N	Y		H+A
	10/30/2003	69.40	69.50	N	N	N	--	--	--	--	--	--	--	--	--	960	803		N	N	Y		H+A
	10/30/2003	72.70	72.80	N	N	Y	670	<630	<630	<630	<630	<630	1,700	1,700	2,370	7,315	2,202	Strong Odor	Y	N	N	Lab	H+A
	10/30/2003	77.40	77.50	Y	Y	Y	1,400	<400	<400	<400	<400	<400	1,100	1,100	2,500	5,780	2,320	Oil Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab.	H+A
	10/30/2003	81.00	81.10	N	N	N	--	--	--	--	--	--	--	--	--	1,060	895		N	N	Y		H+A
	10/30/2003	83.80	83.90	N	N	N	--	--	--	--	--	--	--	--	--	364	402		N	N	Y		H+A
	10/30/2003	90.00	90.10	N	N	N	--	--	--	--	--	--	--	--	--	313	390		N	N	Y		H+A
PSB-14	11/4/2003	62.80	62.90	N	N	N	--	--	--	--	--	--	--	--	--	222	153		N	N	Y		H+A
	11/4/2003	67.80	67.90	N	N	N	--	--	--	--	--	--	--	--	--	57	30		N	N	Y		H+A
	11/4/2003	75.00	75.10	N	N	N	--	--	--	--	--	--	--	--	--	22	12		N	N	Y		H+A
	11/4/2003	75.75	75.85	N	N	N	--	--	--	--	--	--	--	--	--	999	556		N	N	Y		H+A
	11/4/2003	78.50	78.80	Y	Y	Y	8,600	<3,500	<3,500	<3,500	<3,500	<3,500	<3,500	9,800	18,500	1,642	1,256	Oily Sheen, Very Strong Odor.	Y	N	N	FLUTe, Visual, Lab.	H+A
	11/4/2003	83.00	83.10	N	N	N	--	--	--	--	--	--	--	--	--	123	--		N	N	Y		H+A
	11/4/2003	89.00	89.10	N	N	N	--	--	--	--	--	--	--	--	--	57	39		N	N	Y		H+A
	11/4/2003	91.00	91.10	N	N	N	--	--	--	--	--	--	--	--	--	158	111		N	N	Y		H+A
	11/4/2003	93.50	93.60	N	N	Y	<40	<40	<40	<40	<40	<40	<40	<40	<40	481	206		N	N	Y		H+A
	11/4/2003	93.90	94.00	N	N	N	--	--	--	--	--	--	--	--	--	185	129		N	N	Y		H+A
PSB-15	11/5/2003	62.90	63.00	N	N	N	--	--	--	--	--	--	--	--	--	41	29		N	N	Y		H+A
	11/5/2003	67.00	67.10	N	N	N	--	--	--	--	--	--	--	--	--	820	450		N	N	Y		H+A
	11/5/2003	71.20	71.30	Y	Y	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	FLUTe, Visual	H+A
	11/5/2003	74.90	75.20	Y	Y	Y	9,000	<2,000	<2,000	2,600	<2,000	<2,000	8,600	11,200	20,200	10,400	1,400	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
	11/5/2003	79.00	79.10	N	N	N	--	--	--	--	--	--	--	--	--	10,300	2,000		Y	N	N	Headspace	H+A
	11/5/2003	79.40	79.50	Y	Y	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	FLUTe, Visual	H+A
	11/5/2003	79.60	79.90	Y	Y	Y	13,000	<3,300	<3,300	<3,300	<3,300	<3,300	11,000	11,000	24,000	--	--	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab.	H+A
	11/5/2003	80.20	80.30	Y	Y	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	FLUTe, Visual	H+A
	11/5/2003	83.00	83.10	N	N	N	--	--	--	--	--	--	--	--	--	64	47		N	N	Y		H+A
	11/5/2003	87.50	87.60	N	N	N	--	--	--	--	--	--	--	--	--	74	42		N	N	Y		H+A
	11/5/2003	91.50	91.60	N	N	N	--	--	--	--	--	--	--	--	--	529	225		N	N	Y		H+A
	11/5/2003	93.00	93.10	N	N	N	--	--	--	--	--	--	--	--	--	236	142		N	N	Y		H+A

Table D-1
DNAPL Characterization as Definite or Possible in Saturated UBA
Montrose Superfund Site

DNAPL Presence Line of Evidence				Primary			Secondary												DNAPL Occurrence			Basis For Definition	Consultant
		Depth Interval		Visual	FLUTe	Soil	MCB	2,4'-DDD	2,4'-DDE	2,4'-DDT	4,4'-DDD	4,4'-DDE	4,4'-DDT	Total DDT	DNAPL Conc.	FID	PID	Boring Log			Not		
Boring ID	Sample Date	Top	Bottom	Observation	Stain	Sample	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(ppmv)	(ppmv)	Notes[1]	Definite	Possible	Present		
PSB-17	11/10/2003	61.00	61.10	N	N	N	--	--	--	--	--	--	--	--	--	69	54		N	N	Y		H+A
	11/10/2003	66.00	66.10	N	N	N	--	--	--	--	--	--	--	--	--	342	253		N	N	Y		H+A
	11/10/2003	70.50	70.60	N	N	N	--	--	--	--	--	--	--	--	--	350	260		N	N	Y		H+A
	11/10/2003	78.00	78.10	N	N	N	--	--	--	--	--	--	--	--	--	79	85		N	N	Y		H+A
	11/10/2003	82.00	82.10	N	N	N	--	--	--	--	--	--	--	--	--	97	86		N	N	Y		H+A
	11/10/2003	85.00	85.10	N	N	N	--	--	--	--	--	--	--	--	--	578	380		N	N	Y		H+A
	11/10/2003	87.50	87.60	Y	Y	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
	11/10/2003	88.20	88.40	Y	Y	Y	9,300	<2,000	<2,000	2,200	<2,000	<2,000	10,000	12,200	21,500	10,300	1,289	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
	11/10/2003	94.00	94.10	N	N	Y	<34	<34	<34	<34	<34	<34	<34	<34	<34	111	80		N	N	Y		H+A
PSB-18	11/22/2003	64.00	64.10	N	N	N	--	--	--	--	--	--	--	--		43	27		N	N	Y		H+A
	11/22/2003	68.00	68.10	N	N	N	--	--	--	--	--	--	--	--		283	239		N	N	Y		H+A
	11/22/2003	68.90	69.00	N	N	Y	400	<400	<400	510	<400	<400	1,500	2,010	2,410	3,000	1,460	Strong Odor	Y	N	N	Lab	H+A
	11/22/2003	73.00	73.10	N	N	N	--	--	--	--	--	--	--	--	0	320	230		N	N	Y		H+A
	11/22/2003	77.00	77.10	N	N	N	--	--	--	--	--	--	--	--	0	300	265		N	N	Y		H+A
	11/22/2003	81.00	81.10	N	N	N	--	--	--	--	--	--	--	--	0	850	620		N	N	Y		H+A
	11/22/2003	85.00	85.10	N	N	N	--	--	--	--	--	--	--	--	0	260	186		N	N	Y		H+A
	11/22/2003	88.50	88.60	N	N	Y	5,700	<1,800	<1,800	<1,800	<1,800	<1,800	5,900	5,900	11,600	5,000	1,000	Strong Odor	Y	N	N	Lab	H+A
	11/22/2003	95.00	95.10	N	N	N	--	--	--	--	--	--	--	--		526	237		N	N	Y		H+A
PSB-19	11/23/2003	61.00	61.10	N	N	N	--	--	--	--	--	--	--	--	--	42	69		N	N	Y		H+A
	11/23/2003	65.00	65.10	N	N	N	--	--	--	--	--	--	--	--	--	270	227		N	N	Y		H+A
	11/23/2003	69.00	69.10	N	N	N	--	--	--	--	--	--	--	--	--	365	317		N	N	Y		H+A
	11/23/2003	71.80	71.90	N	N	Y	<40	<40	<40	<40	<40	<40	<40	<40	<40	1,220	590		N	N	Y		H+A
	11/23/2003	75.00	75.10	N	N	N	--	--	--	--	--	--	--	--	--	167	288		N	N	Y		H+A
	11/23/2003	77.10	77.20	Y	Y	Y	5,200	<1,500	<1,500	1,500	<1,500	<1,500	3,900	5,400	10,600	17,500	1,318	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
	11/23/2003	78.75	78.85	N	N	N	--	--	--	--	--	--	--	--	--	3,145	901		N	Y	N	Headspace	H+A
	11/23/2003	81.50	81.60	N	N	N	--	--	--	--	--	--	--	--	--	686	350		N	N	Y		H+A
	11/23/2003	86.00	86.10	N	N	N	--	--	--	--	--	--	--	--	--	138	116		N	N	Y		H+A
	11/23/2003	87.75	87.85	N	N	N	--	--	--	--	--	--	--	--	--	275	144		N	N	Y		H+A
	11/23/2003	90.00	90.10	N	N	N	--	--	--	--	--	--	--	--	--	223	159		N	N	Y		H+A
	11/23/2003	93.00	93.10	N	N	N	--	--	--	--	--	--	--	--	--	709	401		N	N	Y		H+A
SSB-2	10/21/2003	61.10	61.20	N	N	N	--	--	--	--	--	--	--	--	--	155	88		N	N	Y		H+A
	10/21/2003	67.00	67.10	N	N	N	--	--	--	--	--	--	--	--	--	12	17		N	N	Y		H+A
	10/21/2003	77.00	77.10	N	N	Y	<30	<30	<30	<30	<30	<30	<30	<30	<30	332	128		N	N	Y		H+A
	10/21/2003	79.10	79.20	N	N	N	--	--	--	--	--	--	--	--	--	138	124		N	N	Y		H+A
	10/21/2003	86.00	86.10	Y	Y	N	--	--	--	--	--	--	--	--	--	20,900	1,492	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Headspace	H+A
	10/21/2003	86.50	87.50	Y	Y	Y	23,000	<2,900	<2,900	6,800	<2,900	<2,900	19,000	25,800	48,800	--	--		Y	N	N	FLUTe, Visual, Lab	H+A
	10/21/2003	88.50	88.60	Y	Y	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	FLUTe, Visual	H+A
SSB-3	10/22/2003	63.00	63.10	N	N	N	--	--	--	--	--	--	--	--	--	100	57		N	N	N		H+A
	10/22/2003	66.50	66.60	N	N	N	--	--	--	--	--	--	--	--	--	1,558	901		N	Y	N	Headspace	H+A
	10/22/2003	69.00	69.10	N	N	N	--	--	--	--	--	--	--	--	--	1,072	800		N	N	Y		H+A
	10/22/2003	74.00	74.10	N	N	N	--	--	--	--	--	--	--	--	--	135	100		N	N	Y		H+A
	10/22/2003	79.00	79.10	N	N	N	--	--	--	--	--	--	--	--	--	237	190		N	N	Y		H+A
	10/22/2003	86.00	86.10	N	N	Y	<40	<40	<40	<40	<40	<40	<40	<40	<40	69	49		N	N	Y		H+A
	10/22/2003	90.00	90.10	N	N	Y	<34	<34	<34	<34	<34	<34	<34	<34	<34	225	191		N	N	Y		H+A
SSB-5	10/24/2003	65.00	65.10	N	N	N	--	--	--	--	--	--	--	--	--	--	73		N	N	Y		H+A
	10/24/2003	69.00	69.10	N	N	N	--	--	--	--	--	--	--	--	--	--	22		N	N	Y		H+A
	10/24/2003	75.00	75.10	N	N	N	--	--	--	--	--	--	--	--	--	--	165		N	N	Y		H+A
	10/24/2003	76.40	76.50	N	Y	N	--	--	--	--	--	--	--	--	--	--	2,519		Y	N	N	FLUTe	H+A
	10/24/2003	77.75	77.85	Y	Y	Y	2,200	<340	<340	530	<340	<340	1,800	2,330	4,530	--	1,995	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab	H+A
	10/24/2003	80.00	80.10	N	N	N	--	--	--	--	--	--	--	--	--	--	392		N	N	Y		H+A
	10/24/2003	82.25	82.35	Y	Y	N	--	--	--	--	--	--	--	--	--	--	1,007		Y	N	N	FLUTe, Visual	H+A
	10/24/2003	88.00	88.10	N	N	N	--	--	--	--	--	--	--	--	--	--	182		N	N	Y		H+A
	10/24/2003	94.50	94.60	N	N	Y	39	<33	<33	<33	<33	<33	<33	<33	39	--	210		N	N	Y		H+A
SSB-6	11/6/2003	61.00	61.10	N	N	N	--	--	--	--	--	--	--	--	--	239	141		N	N	Y		H+A
	11/6/2003	65.00	65.10	N	N	N	--	--	--	--	--	--	--	--	--	400	239		N	N	Y		H+A
	11/6/2003	67.00	67.10	N	N	N	--	--	--	--	--	--	--	--	--	513	320		N	N	Y		H+A
	11/6/2003	71.00	71.10	N	N	N	--	--	--	--	--	--	--	--	--	662	344		N	N	Y		H+A
	11/6/2003	74.00	74.10	N	N	N	--	--	--	--	--	--	--	--	--	127	81		N	N	Y		H+A
	11/6/2003	77.50	77.60	Y	Y	Y	15,000	<3,100	<3,100	<3,100	<3,100	<3,100	<3,100	10,000	25,000	9,500	2,020	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab	H+A
	11/6/2003	80.00	80.10	N	N	N	--	--	--	--	--	--	--	--	--	300	230		N	N	Y		H+A
	11/6/2003	85.50	85.60	N	N	N	--	--	--	--	--	--	--	--	--	274	169		N	N	Y		H+A
	11/6/2003	87.00	87.10	N	N	N	--	--	--	--	--	--	--	--	--	381	257		N	N	Y		H+A
	11/6/2003	88.00	88.10	N	N	Y	<32	<32	<32	<32	<32	<32	<32	<32	<32	1,472	820		N	N	Y		H+A
	11/6/2003	89.00	89.50	Y	Y	Y	55,000	<30,000	<30,000	<30,000	<30,000	<30,000	<30,000	35,000	90,000	--	--	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab	H+A
	11/6/2003	90.50	90.80	Y	Y	Y	49,000	<28,000	<28,000	<28,000	<28,000	<28,000	<28,000	<28,000	49,000	16,300	2,652	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
	11/6/2003	94.00	94.10	N	N	N	--	--	--	--	--	--	--	--	--	471	250		N	N	Y		H+A
SSB-7	11/11/2003	65.00	65.10	N	N	N	--	--	--	--	--	--	--	--	--	415	225		N	N	Y		H+A
	11/11/2003	74.00	74.10	N	N	N	--	--	--	--	--	--	--	--	--	148	117		N	N	Y		H+A
	11/11/2003	83.00	83.10	N	N	N	--	--	--	--	--	--	--	--	--	230	188		N	N	Y		H+A
	11/11/2003	89.40	89.50	N	N	Y	<2,000	<2,000	<2,000	<2,000	<2,000	<2,000	6,200	6,200	6,200	1,901	750		Y	N	N	Lab	H+A
	11/11/2003	94.00	94.10	N	N	Y	<40	<40	<40	<40	<40	<40	<40	<40	<40	58	64		N	N	Y		H+A

BOE-C6-0060015

Table D-1
DNAPL Characterization as Definite or Possible in Saturated UBA
Montrose Superfund Site

DNAPL Presence Line of Evidence				Primary			Secondary												DNAPL Occurrence			Basis For Definition	Consultant
		Depth Interval																					
Boring ID	Sample Date	Top	Bottom	Visual Observation	FLUTe Stain	Soil Sample	MCB (mg/kg)	2,4'-DDD (mg/kg)	2,4'-DDE (mg/kg)	2,4'-DDT (mg/kg)	4,4'-DDD (mg/kg)	4,4'-DDE (mg/kg)	4,4'-DDT (mg/kg)	Total DDT (mg/kg)	DNAPL Conc. (mg/kg)	FID (ppmv)	PID (ppmv)	Boring Log Notes[1]	Definite	Possible	Not Present		
SSB-11	11/19/2003	63.00	63.10	N	N	N	--	--	--	--	--	--	--	--	--	368	236		N	N	Y		H+A
	11/19/2003	65.00	65.10	N	N	N	--	--	--	--	--	--	--	--	--	71	76		N	N	Y		H+A
	11/19/2003	71.00	71.10	N	N	N	--	--	--	--	--	--	--	--	--	11	33		N	N	Y		H+A
	11/19/2003	74.00	74.10	N	N	N	--	--	--	--	--	--	--	--	--	50	58		N	N	Y		H+A
	11/19/2003	78.00	78.10	N	N	Y	990	<350	<350	<350	<350	<350	1,400	1,400	2,390	7,500	1,800	Very Strong Odor	Y	N	N	Lab	H+A
	11/19/2003	83.00	83.10	N	N	N	--	--	--	--	--	--	--	--	--	945	370		N	N	Y		H+A
	11/19/2003	85.50	85.60	N	N	N	--	--	--	--	--	--	--	--	--	1,270	550		N	N	Y		H+A
	11/19/2003	97.00	97.10	N	N	Y	40	<40	<40	<40	<40	<40	<40	<40	40	1020	472	Strong Odor	N	N	Y		H+A
SSB-12	11/20/2003	64.90	65.00	N	N	Y	<40	<40	<40	<40	<40	<40	<40	<40	<40	401	261		N	N	Y		H+A
	11/20/2003	74.00	74.10	N	N	N	--	--	--	--	--	--	--	--	--	274	241		N	N	Y		H+A
	11/20/2003	82.40	82.70	Y	Y	Y	50,000	<20,000	<20,000	<20,000	<20,000	<20,000	53,000	53,000	103,000	7,400	1,710	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab.	H+A
	11/20/2003	88.50	88.60	N	N	N	--	--	--	--	--	--	--	--	--	858	436		N	N	Y		H+A
TSB-2	11/17/2003	65.00	65.10	N	N	N	--	--	--	--	--	--	--	--	--	79	49		N	N	Y		H+A
	11/17/2003	69.50	69.60	N	N	N	--	--	--	--	--	--	--	--	--	17	20		N	N	Y		H+A
	11/17/2003	75.00	75.10	N	N	N	--	--	--	--	--	--	--	--	--	352	193		N	N	Y		H+A
	11/17/2003	78.75	78.85	N	N	Y	54	<36	<36	<36	<36	<36	<36	<36	54	1,040	427	Odor	N	N	Y		H+A
	11/17/2003	82.75	82.85	N	N	N	--	--	--	--	--	--	--	--	--	316	168		N	N	Y		H+A
	11/17/2003	87.60	87.80	Y	Y	Y	28,000	<4,000	<4,000	4,700	<4,000	<4,000	16,000	20,700	48,700	17,300	1,139	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
	11/17/2003	91.00	91.10	N	N	N	--	--	--	--	--	--	--	--	--	58	39		N	N	Y		H+A
TSB-3	11/25/2003	60.00	60.10	N	N	N	--	--	--	--	--	--	--	--	--	145	133		N	N	Y		H+A
	11/25/2003	64.00	64.10	N	N	N	--	--	--	--	--	--	--	--	--	218	159		N	N	Y		H+A
	11/25/2003	68.00	68.10	N	N	N	--	--	--	--	--	--	--	--	--	134	81		N	N	Y		H+A
	11/25/2003	71.00	71.10	N	N	N	--	--	--	--	--	--	--	--	--	23	29		N	N	Y		H+A
	11/25/2003	74.00	74.10	N	N	N	--	--	--	--	--	--	--	--	--	17	28		N	N	Y		H+A
	11/25/2003	74.70	74.80	N	N	Y	<36	<36	<36	<36	<36	<36	<36	<36	<36	47	58		N	N	Y		H+A
	11/25/2003	79.20	79.30	Y	Y	Y	14,000	<2,000	<2,000	3,000	<2,000	<2,000	9,900	12,900	26,900	23,000	1,530	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
	11/25/2003	80.90	81.00	N	N	N	--	--	--	--	--	--	--	--	--	41,000	1,552		Y	N	N	Headspace	H+A
	11/25/2003	84.90	85.00	N	N	N	--	--	--	--	--	--	--	--	--	63,000	1,582		Y	N	N	Headspace	H+A
	11/25/2003	82.00	82.10	N	N	N	--	--	--	--	--	--	--	--	--	292	305		N	N	Y		H+A
	11/25/2003	90.50	90.60	N	N	N	--	--	--	--	--	--	--	--	--	873	530		N	N	Y		H+A
	11/25/2003	92.50	92.60	N	N	N	--	--	--	--	--	--	--	--	--	567	313		N	N	Y		H+A
	11/25/2003	95.00	95.10	N	N	Y	34	<32	<32	<32	<32	<32	<32	<32	<32	674	551		N	N	Y		H+A
TSB-8	1/22/2004	63.50	63.60	N	N	N	--	--	--	--	--	--	--	--	--	6	5		N	N	Y		H+A
	1/22/2004	64.75	64.85	N	N	N	--	--	--	--	--	--	--	--	--	3	2		N	N	Y		H+A
	1/22/2004	69.25	69.35	N	N	N	--	--	--	--	--	--	--	--	--	7	6		N	N	Y		H+A
	1/22/2004	74.25	74.35	N	N	N	--	--	--	--	--	--	--	--	--	36	26		N	N	Y		H+A
	1/22/2004	79.00	79.10	N	N	N	--	--	--	--	--	--	--	--	--	68	47		N	N	Y		H+A
	1/22/2004	81.00	81.10	N	N	N	--	--	--	--	--	--	--	--	--	1,828	709		N	Y	N	Headspace	H+A
	1/22/2004	85.00	85.10	N	N	N	--	--	--	--	--	--	--	--	--	1,210	657		N	N	Y		H+A
	1/22/2004	87.00	87.30	Y	Y	Y	5,100	<1,700	<1,700	<1,700	<1,700	<1,700	3,200	3,200	8,300	37,600	1,563	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Lab, Headspace	H+A
	1/22/2004	90.80	91.00	Y	Y	N	--	--	--	--	--	--	--	--	--	10,800	1,413	Oily Sheen, Very Strong Odor	Y	N	N	FLUTe, Visual, Headspace	H+A
	1/22/2004	91.00	91.50	N	N	Y	13,000	<3,500	<3,500	<3,500	<3,500	<3,500	8,000	8,000	21,000	2,620	1,078		Y	N	N	Lab	H+A
	1/22/2004	94.00	94.10	N	N	N	--	--	--	--	--	--	--	--	--	316	202		N	N	Y		H+A
TSB-9	1/23/2004	62.00	62.10	N	N	N	--	--	--	--	--	--	--	--	--	56	38		N	N	Y		H+A
	1/23/2004	65.00	65.10	N	N	N	--	--	--	--	--	--	--	--	--	1,169	646		N	N	Y		H+A
	1/23/2004	68.90	69.00	N	N	N	--	--	--	--	--	--	--	--	--	2,763	878		N	Y	N	Headspace	H+A
	1/23/2004	72.50	72.60	N	N	N	--	--	--	--	--	--	--	--	--	1,118	611		N	N	Y		H+A
	1/23/2004	76.00	76.10	N	N	N	--	--	--	--	--	--	--	--	--	182	151		N	N	Y		H+A
	1/23/2004	76.60	76.70	N	N	N	--	--	--	--	--	--	--	--	--	9,218	1,248		N	Y	N	Headspace	H+A
	1/23/2004	79.00	79.10	N	N	N	--	--	--	--	--	--	--	--	--	1,453	646		N	N	Y		H+A
	1/23/2004	81.00	81.10	N	N	N	--	--	--	--	--	--	--	--	--	321	242		N	N	Y		H+A
	1/23/2004	85.00	85.10	N	N	N	--	--	--	--	--	--	--	--	--	279	181		N	N	Y		H+A
	1/23/2004	89.00	89.10	N	N	Y	<35	<35	<35	<35	<35	<35	<35	<35	<35	1,217	526	Odor	N	N	Y		H+A
	1/23/2004	91.00	91.10	N	N	Y	47	<35	<35	<35	<35	<35	<35	<35	47	933	406	Odor	N	N	Y		H+A
	1/23/2004	92.00	92.10	N	N	N	--	--	--	--	--	--	--	--	--	1,003	427		N	N	Y		H+A
TSB-11	1/27/2004	65.00	65.10	N	N	N	--	--	--	--	--	--	--	--	--	0	0		N	N	Y		H+A
	1/27/2004	71.00	71.10	N	N	N	--	--	--	--	--	--	--	--	--	19	1		N	N	Y		H+A
	1/27/2004	75.00	75.10	N	N	N	--	--	--	--	--	--	--	--	--	72	49		N	N	Y		H+A
	1/27/2004	77.50	77.60	N	N	N	--	--	--	--	--	--	--	--	--	775	678		N	N	Y		H+A
	1/27/2004	81.00	81.10	N	N	Y	<34	<34	<34	<34	<34	<34	<34	<34	<34	950	690	Odor	N	N	Y		H+A
	1/27/2004	82.50	82.60	N	N	Y	280	<66	<66	<66	<66	<66	100	100	380	4,000	1,900	Odor	N	Y	N	Lab, Headspace	H+A
	1/27/2004	85.00	85.10	N	N	N	--	--	--	--	--	--	--	--	--	125	133		N	N	Y		H+A
	1/27/2004	89.00	89.10	N	N	N	--	--	--	--	--	--	--	--	--	157	189		N	N	Y		H+A
	1/27/2004	91.00	91.10	N	N	Y	<50	<50	<50	<50	<50	<50	<50	<50	<50	74	69		N	N	Y		H+A
C30	5/20/2006	60.00	60.10	N	N	Y	0.39	0.13J	ND	1.0	0.38	ND	1.40	2.91	3.30	114	214		N	N	Y		ET & H+A
	5/20/2006	66.40	66.50	Y	Y	Y**	8,300	<1,600	<1,600	1600	<1,600	<1,600	5000	6,600	14,900	10,800	>10,000		Y	N	N	FLUTe, Visual, Lab, Headspace	ET & H+A
	5/20/2006	70.00	70.10	N	N	Y	3.20	0.049J	ND	0.33	0.16	ND	0.85	1.39	4.59	318	546		N	N	Y		ET & H+A
	5/20/2006	80.00	80.10	N	N	Y	3.70	ND	ND	0.098J	0.052J	ND	0.33	0.48	4.18	106	136		N	N	Y		ET & H+A
	5/20/2006	85.00	85.10	N	N	Y**	120	<110	<110	150	<110	<110	650	800	920	450	1,306		N	Y	N	Lab	ET & H+A
	5/20/2006	90.00	90.10	N	N	Y	40	0.21J	ND	1.9	0.83	ND	4.7	7.64	47.64	318	1,580		N	Y	N	Headspace	ET & H+A

BOE-C6-0060016

Table D-1
DNAPL Characterization as Definite or Possible in Saturated UBA
Montrose Superfund Site

DNAPL Presence Line of Evidence				Primary			Secondary												DNAPL Occurrence			Basis For Definition	Consultant
		Depth Interval		Visual	FLUTe	Soil	MCB	2,4'-DDD	2,4'-DDE	2,4'-DDT	4,4'-DDD	4,4'-DDE	4,4'-DDT	Total DDT	DNAPL Conc.	FID	PID	Boring Log			Not		
Boring ID	Sample Date	Top	Bottom	Observation	Stain	Sample	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(ppmv)	(ppmv)	Notes[1]	Definite	Possible	Present		
C44	5/19/2006	60.00	60.10	N	N	Y	0.01	0.012	0.0067	ND	0.03	0.0160	0.0075	0.0722	0.0842	9	19		N	N	Y		ET & H+A
	5/19/2006	65.00	65.10	N	N	N	--	--	--	--	--	--	--	--	--	320	1,100		N	N	Y		ET & H+A
	5/19/2006	70.00	70.10	N	N	Y	11	0.01	ND	ND	0.0074	0.0044J	0.0036J	0.02	11.02	223	1,029		N	N	Y		ET & H+A
	5/19/2006	76.70	76.80	N	N	Y**	62	<32	<32	<32	<32	<32	<32	<32	62	640	962		N	N	Y		ET & H+A
	5/19/2006	80.00	80.10	Y	Y	Y	25	ND	ND	0.10	0.051J	ND	0.44J	0.59	25.59	1,019	>10,000		Y	N	N	FLUTe, Visual, Headspace	ET & H+A
	5/19/2006	81.00	81.10	N	N	Y**	4,100	<760	<760	960	<760	<760	2,900	3,860	7,960	13,000	>10,000		Y	N	N	Headspace, Lab	ET & H+A
	5/19/2006	85.00	85.10	N	N	N	--	--	--	--	--	--	--	--	--	154	210		N	N	Y		ET & H+A
	5/19/2006	90.00	90.10	N	N	Y	3.20	ND	ND	0.041J	ND	ND	0.22	0.26	3.46	368	1,011		N	N	Y		ET & H+A
S101/101A	11/1/1988	69.30	69.40	Y	--	Y	1,200	<5,000	<2,500	<2,500	<5,000	<2,500	11,000	11,000	12,200	--	--		Y	N	N	Visual, Lab	H+A
	11/1/1988	73.70	73.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	11/1/1988	74.60	74.70	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	11/1/1988	87.50	87.60	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	11/1/1988	89.20	89.30	Y	--	Y	36,000	<10,000	<5,000	<5,000	14,000	<5,000	37,000	51,000	87,000	--	--		Y	N	N	Visual, Lab	H+A
S301/301A	10/25/1988	60.40	60.50	N	--	Y	0.90	<1	<05	<05	1.10	<0.5	2.70	3.80	4.70	--	--		N	N	Y		H+A
	10/25/1988	60.90	61.00	N	--	Y	--	--	--	--	0.04	0.03	0.84	0.91	0.91	--	--		N	N	Y		H+A
	10/14/1988	72.60	72.70	N	--	Y	15	<0.6	<0.3	<0.3	0.64	<0.3	2.10	2.74	17.74	--	--		N	N	Y		H+A
	10/14/1988	75.10	75.20	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	10/14/1988	75.70	75.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	10/14/1988	77.00	77.10	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	10/14/1988	79.50	79.60	Y	--	Y	11,000	<5,000	<2,500	<2,500	<5,000	<2,500	3,900	3,900	14,900	--	--		Y	N	N	Visual, Lab	H+A
	10/14/1988	81.70	81.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	10/14/1988	82.10	82.20	Y	--	Y	4.30	<2.5	<1.3	<1.3	2.9	<1.3	9.3	12.2	16.5	--	--		Y	N	N	Visual	H+A
	10/14/1988	89.50	89.70	Y	--	Y	12,000	<5,000	<2,500	<2,500	<5,000	<2,500	3,800	3,800	15,800	--	--		Y	N	N	Visual, Lab	H+A
S302,A,F	10/17/1988	73.50	73.60	N	--	Y	54	<5	<2.5	<2.5	7.2	8.4	11.0	26.6	80.6	--	--		N	N	Y		H+A
	10/17/1988	74.50	74.60	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	10/17/1988	76.00	76.30	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	10/18/1988	79.50	79.60	Y	--	Y	8.90	<10	5.5	<5	21.0	25.0	36.0	87.5	96.4	--	--		Y	N	N	Visual	H+A
	10/18/1988	80.40	80.50	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	10/18/1988	81.70	81.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	10/18/1988	98.00	98.10	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	10/18/1988	99.70	99.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
S304/304A	10/13/1988	78.20	78.30	Y	--	Y	4,400	<25,000	<13,000	<13,000	<25,000	<13,000	69,000	69,000	73,400	--	--		Y	N	N	Visual, Lab	H+A
	10/13/1988	78.70	78.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	
	10/13/1988	80.90	81.00	Y	--	Y	4,900	<25,000	<13,000	<13,000	<25,000	<13,000	51,000	51,000	55,900	--	--		Y	N	N	Visual, Lab	H+A
	10/13/1988	81.30	81.40	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
S305/S305A	9/26/1988	64.30	64.40	N	--	Y	9.60	<1	<0.5	<0.5	<1	<0.5	0.55	0.55	10.15	--	--		N	N	Y		H+A
	9/26/1988	73.00	73.20	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	10/16/1988	73.20	73.30	N	--	Y	220	<50	<25	<25	<50	<25	130	130	350				N	Y	N	Lab	H+A
	10/16/1988	73.80	73.90	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	9/26/1988	74.60	74.70	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	9/26/1988	74.70	74.80	N	--	Y	370	<500	<250	<250	<500	<250	540	540	910				N	Y	N	Lab	H+A
	10/16/1988	79.30	79.50	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	10/16/1988	81.50	81.60	N	--	Y	10	<2.5	<1.3	<1.3	<2.5	<1.3	8.40	8.40	18.40	--	--		N	N	Y		H+A
	10/16/1988	90.50	90.60	Y	--	Y	81,000	<10,000	<5,000	<5,000	<10,000	<5,000	24,000	24,000	105,000	--	--		Y	N	N	Visual, Lab	H+A
	10/16/1988	95.00	95.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
UBT-01	Sept - 1989	60.00	62.60	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	62.90	63.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	64.20	64.90	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	65.90	68.10	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	71.10	71.20	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	72.50	72.60	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	72.60	72.70	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	74.00	74.10	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	74.60	74.70	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	74.80	74.90	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	75.20	75.30	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	75.50	75.60	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	75.90	76.00	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	80.90	81.00	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	83.90	84.00	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	86.90	87.00	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	88.30	88.40	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	89.50	89.60	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	89.75	89.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	91.70	91.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	92.40	92.50	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	97.80	97.90	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A

Table D-1
DNAPL Characterization as Definite or Possible in Saturated UBA
Montrose Superfund Site

DNAPL Presence Line of Evidence				Primary			Secondary												DNAPL Occurrence			Basis For Definition	Consultant
		Depth Interval																					
Boring ID	Sample Date	Top	Bottom	Visual Observation	FLUTe Stain	Soil Sample	MCB (mg/kg)	2,4'-DDD (mg/kg)	2,4'-DDE (mg/kg)	2,4'-DDT (mg/kg)	4,4'-DDD (mg/kg)	4,4'-DDE (mg/kg)	4,4'-DDT (mg/kg)	Total DDT (mg/kg)	DNAPL Conc. (mg/kg)	FID (ppmv)	PID (ppmv)	Boring Log Notes[1]	Definite	Possible	Not Present		
UBT-02	Sept - 1989	60.00	60.30	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	62.10	62.20	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	63.40	63.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	64.70	65.20	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	70.40	71.50	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	71.90	72.50	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	74.70	74.90	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	75.20	75.50	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	75.90	76.30	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	76.40	76.50	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	85.20	86.50	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	90.00	90.10	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	90.40	90.50	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	92.35	92.45	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	94.20	94.30	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
UBT-03	Sept - 1989	61.00	61.10	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	69.60	69.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	72.50	73.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	74.60	74.70	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	75.00	75.10	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	75.10	75.20	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	75.60	75.70	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	77.75	77.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	90.05	90.10	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	92.40	93.00	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	Sept - 1989	94.10	94.30	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
LW-1	8/24/1989	79.55	79.75	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	8/24/1989	86.90	87.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A
	8/24/1989	94.60	94.80	Y	--	N	--	--	--	--	--	--	--	--	--	--	--		Y	N	N	Visual	H+A

Notes:
DNAPL Concentration = Total DDT + MCB
[1] Where available; from H+A
* Definite DNAPL occurrence at DP-1 is an error; did not meet the criteria; should be characterized as possible
** Lab data from H+A
mg/kg = milligrams per kilogram
ppmv = parts per million by volume
FID = flame ionization detector
PID = photo ionization detector
ft = feet
H+A = Hargis + Associates, Inc.
ET = Earth Tech, Inc.
MCB = monochlorobenzene
DNAPL = dense non-aqueous phase liquid
DDT = dichlorodiphenyltrichloroethane
DDE = dichlorodiphenyldichloroethene
DDD = dichlorodiphenyldichloroethane
EPA Data Source = Final Remedial Investigation Report (May 1998)
H+A Data Sources = Results of DNAPL Reconnaissance Investigation (Oct 2004); Tech Memo regarding DNAPL Reconnaissance Borings in Support of Earth Tech Soil Sampling Program (Jan 2006); revised DNAPL thickness estimates (May 2008)
ET Data Source = 2005 Soil Sampling Program, final laboratory results and soil boring logs (soil borings C30 and C44 only)
UBA = Upper Bellflower Aquitard

Definite DNAPL Occurrence if:
FLUTe ribbon stain
Visual observation
MCB > 1,000 mg/kg
Total DDT > 1,000 mg/kg
Headspace > 10,000 ppmv

Possible DNAPL Occurrence if:
MCB > 180/230 mg/kg
Total DDT > 60 mg/kg
Headspace > 1,500 ppmv

Appendix E

E1 - Summary of DNAPL Mass Estimates
E2 - Estimated Total DNAPL Mass in Saturated UBA (60-105' bgs)
E3- Estimated DNAPL Mass in Focused Treatment Area Saturated UBA (60-105' bgs)
E4- Estimated Mobile DNAPL Mass in Focused Treatment Area Saturated UBA (60-105' bgs)

TABLE E-1
SUMMARY OF DNAPL MASS ESTIMATES
SATURATED UPPER BELLFLOWER AQUITARD (60-105 FEET BGS)

	Mass Estimates			Calculation Details
	DNAPL (MCB + DDT) (lbs)	DNAPL (gallons)	MCB[1] (DNAPL PHASE) (lbs)	
Total DNAPL Mass in Focused Treatment Area	473,655	41,870	236,828	Table E-3
Mobile DNAPL Mass	221,784	19,544	110,892	Table E-4
Residual DNAPL Mass	251,871	–	125,936	–
DNAPL Mass outside Focused Treatment Area[2]	322,396	–	161,198	–
Total DNAPL Mass At Site	**796,051**	–	**398,026**	Table E-2
% of Total DNAPL Mass in Focused Treatment Area	60%	–	60%	–

Notes:
1. Assumed to be 50 % of the Total DNAPL Mass
2. DNAPL mass outside the focused treatment area is all residual; no mobile DNAPL exists outside the focused treatment area.
MCB = monochlorobenzene
DDT = dichlorodiphenyltrichloroethane
BGS = below grade surface

TABLE E-2
ESTIMATED TOTAL DNAPL MASS IN
SATURATED UPPER BELLFLOWER AQUITARD (60-105 FEET BGS)
CALCULATED USING LIBERAL ESTIMATES OF DNAPL THICKNESS

	Saturated UBA								
Boring ID	**Peak MCB Concentration (mg/kg)**	**Peak Total DDT Concentration (mg/kg)**	**Peak DNAPL Concentration (mg/kg)**	**DNAPL Thickness (feet)**	**Definite Thickness x Concentration (ftxmg/kg/1E6)**	**Contour Area >50,000 mg/kg**	**>10,000 mg/kg**	**>1,000 mg/kg**	**<1,000 mg/kg**
DP-1	480	170	650	0.50	0.0003				0.0003
DP-2	210	110	320	0.00					
DP-3	13,000	8,300	21,300	0.50	0.0107		0.0107		
DP-4	45	<28	45	0.00					
DP-5	3,400	2,400	5,800	0.30	0.0017			0.0017	
DP-7	16,000	12,000	28,000	1.00	0.0280		0.0280		
DP-8	100	<24	100	0.00					
DP-9	<30	<30	<60	0.00					
DP-10	<30	<30	<60	0.00					
DP-11	<28	<28	<56	0.00					
DP-12	550	550	1,100	1.25					
PSB-1	2,400	3,120	5,520	2.50	0.0138			0.0138	
PSB-2	7,100	9,800	16,900	0.85	0.0144		0.0144		
PSB-3	3,000	3,150	6,150	1.75	0.0108			0.0108	
PSB-4	45,000	37,400	82,400	2.95	0.2431	0.2431			
PSB-5	14,000	16,100	30,100	2.50	0.0753	0.0753			
PSB-6	27,000	27,100	54,100	0.35	0.0189	0.0189			
PSB-7	<33	<33	<66	0.00					
PSB-8	<30	<30	<60	0.00					
PSB-9	2,000	1,790	3,790	4.00	0.0152			0.0152	
PSB-10	44	<33	44	0.00					
PSB-11	3,200	8,700	11,900	2.00	0.0238		0.0238		
PSB-12	1,400	1,100	2,500	1.55	0.0039			0.0039	
PSB-13	<51	<51	<102	0.00					
PSB-14	8,600	9,900	18,500	1.00	0.0185		0.0185		
PSB-15	13,000	11,000	24,000	1.75	0.0420		0.0420		
PSB-16	49	<35	49	0.00					
PSB-17	9,300	12,200	21,500	1.00	0.0215		0.0215		
PSB-18	5,700	5,900	11,600	1.75	0.0203		0.0203		
PSB-19	5,200	5,400	10,600	0.25	0.0027		0.0027		
SSB-1	<21	<21	<42	0.00					
SSB-2	23,000	25,800	48,800	2.35	0.1147		0.1147		
SSB-3	<40	<40	<80	0.00					
SSB-4	N/A	N/A	N/A	0.00					
SSB-5	2,200	2,330	4,530	0.95	0.0043			0.0043	
SSB-6	55,000	35,000	90,000	2.50	0.2250	0.2250			
SSB-7	<2,000	6,200	6,200	1.50	0.0093			0.0093	
SSB-8	<40	<40	<80	0.00					
SSB-9	<45	<45	<90	0.00					
SSB-10	<40	<40	<80	0.00					
SSB-11	990	1,400	2,390	0.70	0.0017			0.0017	
SSB-12	50,000	53,000	103,000	1.00	0.1030	0.1030			
SSB-13	<40	<40	<80	0.00					
SSB-14	<40	<40	<80	0.00					
SSB-15	<34	<34	<68	0.00					
TSB-1	<50	<50	<100	0.00					
TSB-2	28,000	20,700	48,700	0.30	0.0146		0.0146		
TSB-3	14,000	12,900	26,900	1.60	0.0430		0.0430		
TSB-4	<30	<30	<60	0.00					
TSB-5	44	<34	44	0.00					
TSB-6	<36	<36	<72	0.00					
TSB-7	<34	<34	<68	0.00					
TSB-8	13,000	8,000	21,000	0.95	0.0200		0.0200		
TSB-9	47	<35	47	0.00					
TSB-10	46	<34	46	0.00					
TSB-11	280	100	380	0.00					
TSB-12	<40	<40	<80	0.00					
TSB-13	45	<40	45	0.00					
TSB-14	40	<35	40	0.00					
TSB-15	<35	<35	<70	0.00					
TSB-16	<40	<40	<80	0.00					
C-13	<30	<30	<60	0.00					
C-30	8,300	6,600	14,900	2.00	0.0298		0.0298		
C-42	<35	<35	<70	0.00					
C-44	4,100	3,860	7,960	1.00	0.0080			0.0080	
C-59	66	<40	66	0.00					
S-101/101A	36,000	51,000	87,000	1.05	0.0914	0.0914			
S-201	N/A	N/A	N/A	N/A					
S-202	N/A	N/A	N/A	N/A					
S-203	N/A	N/A	N/A	N/A					
S-204	N/A	N/A	N/A	N/A					
S-301/301A	12,000	3,800	15,800	1.20	0.0190		0.0190		
S-302A	54	88	142	1.45	0.0002				0.0002
S-302E/302F	N/A	N/A	N/A	1.45					
S-303/303A	1	8	9	0.00					
S-304/304A	4,900	69,000	73,900	1.00	0.0739	0.0739			
S-305/305A	81,000	24,000	105,000	2.20	0.2310	0.2310			
MW-2	7,400	4,980	12,380	N/A					
UBT-1	N/A	N/A	N/A	14.15		0.2310			
UBT-2	N/A	N/A	N/A	7.55		0.2310			
UBT-3	N/A	N/A	N/A	4.50		0.2310			
LW-1	N/A	N/A	N/A	1.30					

Notes:

For purposes of DNAPL mass estimation, recovery wells UBT-1 through UBT-3 were assigned a (thickness x concentration) product of 0.2310 ft x mg/kg/1E6, consistent with the value measured at S-305/305A.

	>50,000 mg/kg	>10,000 mg/kg	>1,000 mg/kg	<1,000 mg/kg	
Average (ft x mg/kg / 1E6) =	**0.1595**	**0.0282**	**0.0076**	**0.0003**	**Subtotal**
Area (sq ft) =	**30,492**	**58,141**	**50,447**	**23,045**	**162,125**
Wet bulk density (g/cc) =	**1.85**	**1.85**	**1.85**	**1.85**	
DNAPL Mass (lbs) =	**561,686**	**189,267**	**44,391**	**706**	**796,051**
% of Total Mass =	**70.6%**	**23.8%**	**5.6%**	**0.1%**	**100.0%**

TABLE E-3
ESTIMATED DNAPL MASS IN FOCUSED TREATMENT AREA
SATURATED UPPER BELLFLOWER AQUITARD (60-105 FEET BGS)
CALCULATED USING LIBERAL ESTIMATES OF DNAPL THICKNESS

	Saturated UBA				Definite DNAPL Thickness x Concentration (ftxmg/kg/1E6)	
Boring ID	**Peak MCB Concentration (mg/kg)**	**Peak Total DDT Concentration (mg/kg)**	**Peak DNAPL Concentration (mg/kg)**	**DNAPL Thickness (feet)**	**Focused Treatment Area**	**SSB-12 Area**
PSB-4	45,000	37,400	82,400	2.95	0.24308	
PSB-5	14,000	16,100	30,100	2.50	0.07525	
PSB-6	27,000	27,100	54,100	0.35	0.018935	
SSB-6	55,000	35,000	90,000	2.50	0.225	
SSB-12	50,000	53,000	103,000	1.00		0.103
S-101/101A	36,000	51,000	87,000	1.05	0.09135	
S-304/304A	4,900	69,000	73,900	1.00	0.0739	
S-305/305A	81,000	24,000	105,000	2.20	0.231	
UBT-1	N/A	N/A	N/A	14.15	0.231*	
UBT-2	N/A	N/A	N/A	7.55	0.231*	
UBT-3	N/A	N/A	N/A	4.50	0.231*	

Average (ft x mg/kg / 1E6) =	**0.1652**	**0.103**	**Total**
Area (sq ft) =	**22,900**	**3,100**	**26,000**
Wet bulk density (g/cc) =	**1.85**	**1.85**	
Total DNAPL Mass (lbs) =	**436,779**	**36,876**	**473,655**
DNAPL density (g/cc) =	**1.25**	**1.25**	
Total DNAPL Volume (gals) =	**41,870**	**3,535**	**45,405**

Notes:

*For purposes of mobile DNAPL mass estimation, recovery wells UBT-1 through UBT-3 were assigned a (thickness x concentration) product of 0.078 ft x mg/kg/1E6, consistent with the value measured at S-305/305A.

TABLE E-4
ESTIMATED MOBILE DNAPL MASS IN FOCUSED TREATMENT AREA
SATURATED UPPER BELLFLOWER AQUITARD (60-105 FEET BGS)
CALCULATED USING LIBERAL ESTIMATES OF DNAPL THICKNESS

	Saturated UBA					Definite DNAPL Thickness x Concentration (ftxmg/kg/1E6)	
Boring ID	Peak MCB Concentration (mg/kg)	Peak Total DDT Concentration (mg/kg)	Peak DNAPL Concentration (mg/kg)	DNAPL Thickness (feet)	(Peak Conc - Assumed Residual Concentration of 53,000) (mg/kg)	Focused Treatment Area	SSB-12 Area
PSB-4	45,000	37,400	82,400	2.95	29,400	0.08673	
PSB-6	27,000	27,100	54,100	0.35	1,100	0.000385	
SSB-6	55,000	35,000	90,000	2.50	37,000	0.0925	
SSB-12	50,000	53,000	103,000	1.00	50,000		0.05
S-101/101A	36,000	51,000	87,000	1.05	34,000	0.0357	
S-304/304A	4,900	69,000	73,900	1.00	20,900	0.0209	
S-305/305A	81,000	24,000	105,000	2.20	52,000	0.1144	
UBT-1	N/A	N/A	N/A	14.15		0.1144*	
UBT-2	N/A	N/A	N/A	7.55		0.1144*	
UBT-3	N/A	N/A	N/A	4.50		0.1144*	

Notes:

*For purposes of mobile DNAPL mass estimation, recovery wells UBT-1 through UBT-3 were assigned a (thickness x concentration) product of 0.078 ft x mg/kg/1E6, consistent with the value measured at S-305/305A.

	Focused Treatment Area	SSB-12 Area	Total
Average (ft x mg/kg / 1E6) =	0.0771	0.05	
Area (sq ft) =	22,900	3,100	26,000
Wet bulk density (g/cc) =	1.85	1.85	
Mobile DNAPL Mass (lbs) =	203,883	17,901	221,784
DNAPL density (g/cc) =	1.25	1.25	
Mobile DNAPL Volume (gals) =	19,544	1,716	21,260

Appendix F

F-1 – Passive DNAPL Recovery Since 1988

TABLE F-1

PASSIVE DNAPL RECOVERY SINCE 1988
MONTROSE SUPERFUND SITE

	UBA WELL										
	MW-2	UBT-1	UBT-2	UBT-3	UBE-1	UBE-2	UBE-3	UBE-4	UBE-5	TOTAL	CUMULATIVE TOTAL
DATE	VOLUME DNAPL PURGED (gallons)										
01/18/1988	0.26	--	--	--	--	--	--	--	--	0.26	0.26
02/04/1988	0.19	--	--	--	--	--	--	--	--	0.19	0.45
03/18/1988	0.16	--	--	--	--	--	--	--	--	0.16	0.61
03/25/1988	0.02	--	--	--	--	--	--	--	--	0.02	0.63
03/31/1988	0.02	--	--	--	--	--	--	--	--	0.02	0.65
04/22/1988	0.03	--	--	--	--	--	--	--	--	0.03	0.68
07/27/1988	0.19	--	--	--	--	--	--	--	--	0.19	0.87
10/14/1988	0.08	--	--	--	--	--	--	--	--	0.08	0.95
02/09/1989	0.06	--	--	--	--	--	--	--	--	0.06	1.01
05/20/1989	0.01	--	--	--	--	--	--	--	--	0.01	1.02
09/25/1989	--	1.00	--	--	--	--	--	--	--	1.00	2.02
10/28/1989	0.05	--	--	--	--	--	--	--	--	0.05	2.07
06/20/1990	0.11	--	0.00	0.53	--	--	--	--	--	0.63	2.70
07/06/1990	0.19	--	0.00	0.01	--	--	--	--	--	0.20	2.91
08/02/1990	0.11	--	0.00	0.01	--	--	--	--	--	0.12	3.03
11/26/1990	0.00	--	0.00	0.00	--	--	--	--	--	0.00	3.03
10/07/1991	0.00	6.50	0.05	3.00	0.00	--	--	--	--	9.55	12.58
11/18/1991	0.00	1.72	0.00	0.00	0.00	--	--	--	--	1.72	14.30
02/21/1992	0.00	3.50	0.00	0.00	0.00	--	--	--	--	3.50	17.80
05/21/1992	0.00	2.00	0.00	0.00	0.00	--	--	--	--	2.00	19.80
07/24/1992	0.75	4.00	0.00	1.00	0.00	--	--	--	--	5.75	25.55
11/19/1992	0.50	1.50	0.00	0.00	0.00	--	--	--	--	2.00	27.55
01/29/1993	1.00	2.00	0.00	0.00	0.00	--	--	--	--	3.00	30.55
06/08/1993	0.50	13.00	0.00	0.00	0.13	--	--	--	--	13.63	44.17
07/23/1993	0.25	4.00	0.50	0.00	0.13	--	--	--	--	4.88	49.05
09/27/1993	0.00	3.00	0.25	0.00	0.50	--	--	--	--	3.75	52.80

TABLE F-1
PASSIVE DNAPL RECOVERY SINCE 1988
MONTROSE SUPERFUND SITE

	UBA WELL										
	MW-2	UBT-1	UBT-2	UBT-3	UBE-1	UBE-2	UBE-3	UBE-4	UBE-5	TOTAL	CUMULATIVE TOTAL
DATE	VOLUME DNAPL PURGED (gallons)										
02/08/1994	0.75	5.00	0.50	0.00	0.75	--	--	--	--	7.00	59.80
05/25/1994	0.60	3.00	0.50	0.60	2.50	--	--	--	--	7.20	67.00
10/06/1994	0.70	2.50	0.60	0.30	2.00	--	--	--	--	6.10	73.10
06/19/1995	0.13	2.50	0.75	0.13	1.50	--	--	--	--	5.00	78.10
10/09/1995	--	2.00	--	1.13	1.13	--	--	--	--	4.25	82.35
12/19/1995	0.25	1.50	1.00	0.25	1.50	--	--	--	--	4.50	86.85
03/14/1997	--	1.50	--	--	--	--	--	--	--	1.50	88.35
10/08/1997	--	--	1.83	1.55	--	--	--	--	--	3.38	91.73
10/29/1998	0.33	1.50	3.00	3.00	4.75	--	--	--	--	12.58	104.31
3/23/1999	0.00	0.40	0.70	2.80	0.00	--	--	--	--	3.90	108.21
6/22/1999	0.30	0.10	0.80	0.80	0.40	--	--	--	--	2.40	110.61
9/30/1999	0.00	0.00	1.00	1.00	0.20	--	--	--	--	2.20	112.81
12/22/1999	0.00	0.20	0.50	1.30	0.00	--	--	--	--	2.00	114.81
3/23/2000	0.00	0.20	0.50	2.00	0.00	--	--	--	--	2.70	117.51
6/28/2000	0.00	0.40	0.60	1.50	0.00	--	--	--	--	2.50	120.01
9/30/2000	0.00	0.40	0.60	1.50	0.00	--	--	--	--	2.50	122.51
12/15/2000	0.00	0.40	0.50	1.30	0.00	--	--	--	--	2.20	124.71
5/24/2001	0.00	0.25	0.50	1.00	0.25	--	--	--	--	2.00	126.71
10/24/2001	0.00	0.25	1.00	2.00	0.05	--	--	--	--	3.30	130.01
3/28/2002	0.02	0.25	0.75	1.00	0.50	--	--	--	--	2.52	132.53
8/29/2002	0.00	0.50	0.30	0.30	0.80	--	--	--	--	1.90	134.43
11/6/2003	0.10	1.30	0.50	0.50	2.40	--	--	--	--	4.80	139.23

TABLE F-1
PASSIVE DNAPL RECOVERY SINCE 1988
MONTROSE SUPERFUND SITE

	UBA WELL										
	MW-2	UBT-1	UBT-2	UBT-3	UBE-1	UBE-2	UBE-3	UBE-4	UBE-5	TOTAL	CUMULATIVE TOTAL
DATE	VOLUME DNAPL PURGED (gallons)										
7/26/2005	0.00	0.25	0.75	0.50	5.50	--	--	--	--	7.00	146.23
8/5/2005	--	--	--	--	--	0.00	0.00	10.75	--	10.75	156.98
12/9/2005	0.00	0.50	0.25	0.00	1.85	0.00	0.00	8.50	--	11.10	168.08
5/25/2006	0.00	0.75	0.13	0.25	1.75	0.00	0.00	9.00	--	11.88	179.96
11/9/2006	0.00	0.25	0.13	0.00	1.50	0.13	0.00	13.00	--	15.01	194.97
4/3/2007	0.00	0.25	0.13	0.00	0.75	0.00	0.00	14.00	--	15.13	210.10
3/7/2008	0.00	0.00	0.25	0.00	1.25	0.25	0.00	19.00	--	20.75	230.85
10/15/2008	0.00	4.00	0.13	0.00	2.25	0.25	0.00	19.00	0.00	25.63	256.47
TOTAL	**7.65**	**72.37**	**19.00**	**29.25**	**34.33**	**0.63**	**0.00**	**93.25**	**0.00**	**256.47**	**256.47**

Notes:
-- = Well not purged on the given date
UBA = Upper Bellflower Aquitard

Appendix G

Technical Memorandum RE: Evaluation of Containment Zone Timeframes
Following a DNAPL Remedy at the Montrose Site, Torrance, California.
Revision 1.0

HARGIS + ASSOCIATES, INC.
HYDROGEOLOGY • ENGINEERING

Mission City Corporate Center
2365 Northside Drive, Suite C-100
San Diego, CA 92108
Phone: 619.521.0165
Fax: 619.521.8580

Technical Memorandum

Via: Email and U.S. Mail **Project No:** 857.04c

Date: March 25, 2009

To: Carolyn d'Almeida, U.S. Environmental Protection Agency

cc: Dr. Eva L. Davis, U.S. Environmental Protection Agency (via email only)
John Dolegowski, CH2M Hill (2 copies)
Joe Kelly, Montrose (via email only)
Paul Sundberg, Montrose (via email only)
Mike Palmer, de maximis, inc. (via email only)
Karl Lytz Esq., Latham & Watkins (via email only)
Kelly Richardson Esq., Latham & Watkins (1 copy)
Brian Dean, Earth Tech (via email only)
Dr. Bernie Kueper, Queens University (via email only)
Dr. Paul Johnson, Arizona State University (via email only)
Dacre Bush, TN & Associates (via email only)
Dr. David Huntley (via email only)

From: Danielle Ondic, PE 6286 Roger Niemeyer, PG 3616, CHG 49

Re: Evaluation of Containment Zone Timeframes Following a DNAPL Remedy at the Montrose Site, Torrance, California, Revision 1.0

This technical memorandum was originally submitted to the U.S. Environmental Protection Agency (EPA) on September 4, 2008. It has been updated in response to EPA comments provided in a letter dated December 23, 2008 (EPA, 2008b) and supersedes the September 4, 2008 memo. Responses to EPA's comments have been prepared and are included as a separate technical memorandum in this transmittal.

This technical memorandum provides an evaluation of the timeframes required for hydraulic containment following potential implementation of a dense non-aqueous phase liquid (DNAPL) remedy at the Montrose Chemical Corporation of California (Montrose) Site in Torrance, California. Given the size of the DNAPL source area in the upper Bellflower aquitard (UBA) and the complexity of the lithology at the Montrose Site, there is no DNAPL remedy that will be able to achieve complete removal of the DNAPL mass. Therefore, even if a DNAPL remedy is selected and implemented, the remaining DNAPL mass will continue to dissolve into the groundwater in the UBA over time, requiring hydraulic containment of the source area in the UBA.

Hydraulic containment of the DNAPL source area in the UBA will be required until groundwater concentrations decline to below the in situ groundwater standard (ISGS) for chlorobenzene of 70 micrograms per liter (ug/l), as specified in the groundwater Record of Decision (ROD)

(EPA, 1999). The concentration of chlorobenzene in groundwater, and thus the need for long-term hydraulic containment, is dependent on the amount of DNAPL mass remaining in the UBA following a DNAPL remedy, and the rate of DNAPL dissolution.

Therefore, this technical memorandum provides estimates of the timeframes required to achieve the ISGS for chlorobenzene following implementation of the various DNAPL remedies being considered. The estimated timeframes will be used to facilitate comparison of these remedial alternatives for effectiveness assessments, including assessments of remedial and cost effectiveness as part of the DNAPL Feasibility Study (FS), as specified by EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988).

Additional information is provided below regarding project background, the approach used to calculate timeframes, assumptions used in the calculations, results of a sensitivity analysis, and a discussion of conclusions and uncertainties.

Background

DNAPL at the Montrose Site, composed primarily of dichlorodiphenyltrichloroethane (DDT) and chlorobenzene, has migrated downward from the land surface into the UBA. DNAPL presence has been confirmed in the saturated portion of the UBA at the Montrose Property to a depth of about 100 feet below land surface (bls) (Hargis + Associates, Inc. [H+A], 2004). The depth of the base of the UBA in the area of DNAPL impact is encountered at about 105 feet. Thus, DNAPL is present at depths near the base of the UBA. This analysis solely focuses on DNAPL in the saturated portion of the UBA and does not address DNAPL that may be present in the underlying Bellflower Sand (BFS)[1].

The estimated aerial extent of DNAPL within the saturated zone of the UBA is approximately 162,000 square feet and is shown in Figure 1. As groundwater in the saturated portion of the UBA contacts the DNAPL, the more soluble component of the DNAPL, chlorobenzene, dissolves. DDT is nearly insoluble in water; therefore, for the purposes of this evaluation, only the dissolution and transport of chlorobenzene in the saturated zone is considered. As chlorobenzene dissolves into groundwater, it migrates horizontally downgradient from the source area creating a dissolved chlorobenzene plume. In addition to the horizontal migration of chlorobenzene within the UBA, the downward vertical gradient between the UBA and the underlying BFS also causes a slight downward flow of groundwater containing dissolved chlorobenzene from the UBA into the BFS.

Various technologies for DNAPL source zone treatment are being considered as part of the DNAPL FS. Based on evaluations being conducted for the FS, hydraulic containment only, hydraulic containment in combination with hydraulic displacement (HD), or hydraulic containment in combination with one of two thermal technologies (i.e., steam injection or electrical resistance heating [ERH]) are candidates for a remedial technology. As part of the

[1] Data obtained from field investigations does not provide conclusive evidence of the presence of DNAPL in the BFS (H+A, 2008).

evaluation of the effectiveness of these technologies, it is important to develop estimates of the residual dissolved chlorobenzene concentrations following implementation of these potential treatment techniques.

Attaining groundwater standards in the NAPL-impacted areas would require virtually complete elimination of the NAPL from the subsurface, which EPA has determined to be technically impracticable (EPA, 1999). EPA therefore designated the region surrounding the DNAPL source area as a technical impracticability waiver zone or containment zone due to the expected difficulty in removing enough of the DNAPL to achieve the 70 ug/l ISGS for chlorobenzene at the Montrose Site (EPA, 1999). The ROD indicates that since NAPL dissolution will continue to occur within the containment zone, it must be contained indefinitely (EPA, 1999). Prior to this evaluation the potential timeframe over which hydraulic containment may be required following a DNAPL remedy had not been evaluated.

Technical Approach

For this evaluation, two published methodologies (Newell & Adamson, and Falta, et al., 2005) were initially considered for use in estimating the time required to reach a specified dissolved phase concentration goal, i.e., the ISGS. For the purposes of evaluating the long-term impacts of partial removal of DNAPL, these methodologies provide a range of estimates and facilitate comparison of the technologies as part of planning level assessments including the development of the DNAPL FS. As further explained below, the method presented by Falta, et al. (2005), was ultimately selected for use in this evaluation.

Therefore, the results presented provide a basis for evaluating the potential operational durations of the hydraulic containment system after applying a source depletion remedy at the Montrose Site.

Newell & Adamson Method

Newell & Adamson (2005) presented four simplified mass-balance models: (1) Step Function Model, (2) Linear Decay Model, (3) First-Order Decay Model, and (4) Compound Model. However, the models presented by Newell & Adamson (2005) are not considered further in this evaluation for two primary reasons:

- Applicability – with the exception of the First-Order Decay Model, the models are not applicable to the conditions observed at the Montrose Site
- Redundancy – with the exception of the Compound Model, the models can be evaluated with the approach presented by Falta, et al. (2005)

The Step Function Model assumes that the mass flux remains constant over time until all of the DNAPL has dissolved. This model describes a theoretical condition, which is not applicable to an actual DNAPL site where the DNAPL dissolution rate would be influenced by a decrease in DNAPL mass over time. The Compound Model is a combination of the Step Function Model and the First-Order Decay Model. Since the Step Function Model, which is not applicable to an actual DNAPL site, is a component of the Compound Model, the Compound Model is also not representative. The Linear Decay Model is unrealistic as well given the complex lithology and DNAPL architecture at the Montrose Site.

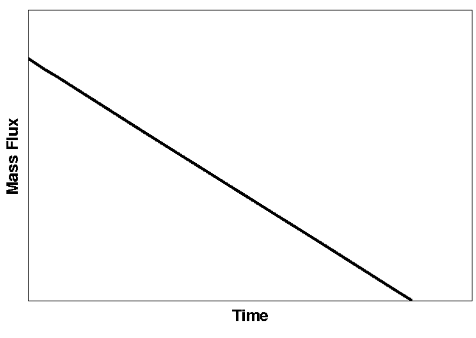
Thus, the only model presented by Newell & Adamson (2005) that is retained for further consideration is the First-Order Decay Model. Since this model can be evaluated using the approach presented by Falta, et al. (2005), as described below, the Newell & Adamson (2005) model was not utilized in this evaluation.

Falta Method

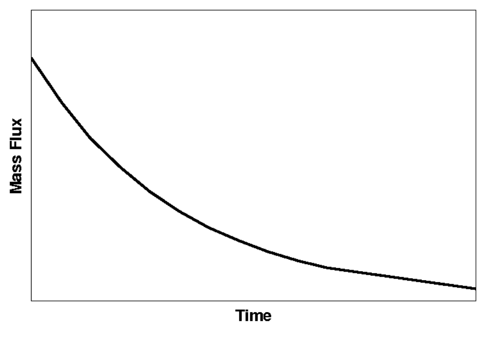
Falta, et al. (2005) presented mass and concentration relationships as a function of time based on a power relationship between the existing DNAPL mass and dissolved phase concentrations emanating from the DNAPL source. The development of this approach was supported by EPA through the National Risk Management Research Laboratory and Strategic Environmental Research and Development Program (Falta, 2005). Additionally, in a recent online EPA seminar (EPA, 2008a) it is noted that a power function relationship, similar to the approach presented by Falta et al.,(2005), is applicable to evaluating dissolution timeframes.

According to the power function model developed by Falta et al. (2005), the dissolved phase concentration is related to the DNAPL mass raised to a power equal to a constant, gamma (Γ). The equations describing this relationship were used to solve for the time to reach the ISGS concentration for chlorobenzene, as described in Attachment A. The exponent, Γ, in the power function equations determines the rate of change in the groundwater concentration (or dissolved mass flux) resulting as DNAPL mass is removed, and is an empirical parameter that defines the relationship between mass and dissolution rates for a given DNAPL architecture.

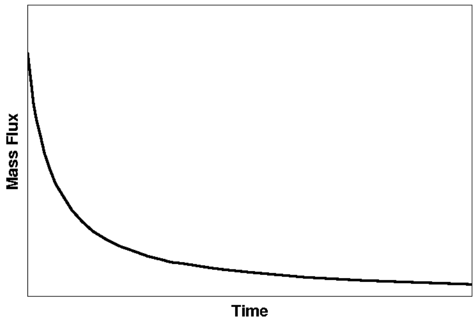
Characteristic decay curves representing a range of Γ values presented in Falta, et al. (2005) are provided below:



Power function, Γ=0.5
(Linear Decay)



Power function, Γ=1
(First Order Decay)



Power function, Γ=2

The Γ value used in the power function equation is a function of a number of parameters including: site lithology, DNAPL architecture after implementation of the remedy, DNAPL saturations, and soil conductivities. Even for homogeneous sites with simple DNAPL distribution, it is not possible to precisely select Γ values. However, evaluation of a range of Γ values ensures that results are representative of the site conditions and bound the likely minimum and maximum results. The general relationship of Γ values to site characteristics, as presented by Falta, et al. (2005), were used to select Γ values that bound the range of conditions observed at the Montrose Site.

Lower Γ values, on the order of 0.5 or less, are typical of source zones where DNAPL tends to reside in high permeability soils and with DNAPL distributed in large horizontal pools. Higher Γ values on the order of 2.0 are typical of heterogeneous source zones where DNAPL is distributed in lower permeability soils. The First-Order Decay Model, when Γ equals 1, represents a commonly assumed median approach for NAPL sites (Newell & Adamson, 2005; Falta, et al., 2005; Parker and Park, 2004) and was therefore selected for use as the base case in this evaluation. Based on direct communication with Dr. Ronald Falta, a gamma value of near 1 is common based on analysis of field and laboratory data.

The assumptions regarding the required input parameters are described in greater detail in the following sections.

It should be noted that DNAPL dissolution models, as described above and as utilized in this analysis, do not explicitly include the effects of slow diffusion of dissolved chlorobenzene from fine-grained layers, commonly referred to as back diffusion. This process is observed following remediation at many sites and results in a long term tailing of dissolved concentrations which can significantly increase the time required to achieve cleanup levels. This issue is discussed further in the section regarding uncertainties in this evaluation.

Assumptions

The Power Function Model used in this evaluation requires input of various parameters including the initial mass of the chlorobenzene component of DNAPL, the initial dissolved phase chlorobenzene concentration, hydraulic properties of the DNAPL zone, hydraulic gradients, and the target dissolved phase chlorobenzene concentration. DNAPL mass is estimated as described in a June 5, 2008 EarthTech memorandum (EarthTech, 2008). This method is based on DNAPL thickness estimates and soil sample concentrations. Since DNAPL is composed of an approximate 50/50 mixture of chlorobenzene and DDT (H+A, 1999), the initial mass of the chlorobenzene component of DNAPL is one half of the initial DNAPL mass. As previously presented to EPA, estimates of DNAPL thickness have been used to estimate DNAPL mass[2] (H+A, 2007 and 2008, EarthTech, 2008). Details regarding the assumptions, including DNAPL thickness estimates used to estimate DNAPL mass, are provided in Attachment A.

In addition to the input parameters indicated above, this evaluation requires estimation of the percentage of the initial chlorobenzene mass that will be removed during a DNAPL remedy. The amount of chlorobenzene mass reduction that can be achieved is dependent, in part, on the remedial technology used and on the treatment area considered.

<u>Hydraulic Displacement</u>

As further explained in Attachment A, the hydraulic displacement technology is effective at removing mobile DNAPL mass. Thus, the treatment area considered for HD, referred to as the focused treatment area and defined as Case 3 in the EarthTech memorandum dated June 5, 2008 (EarthTech, 2008a), is delineated by the extent of mobile DNAPL mass. For this evaluation, the mass reduction percentages that may be achieved by a HD remedy are based DNAPL/water capillary pressure testing conducted on the Montrose DNAPL as well as published information about other sites (Sale, et al, 1997; Gerhard, et al, 2001), as further discussed in Attachment A and shown below.

Table 1. Hydraulic Displacement Mass Reduction

Percent Mobile Chlorobenzene Mass Reduction[(a)]		**Mobile Mass Fraction of Total Mass[(b)]**		**Percent Chlorobenzene Mass Reduction in Entire DNAPL-Impacted Area[(a)]**
60% of mobile DNAPL mass	X	28%	=	17%
80% of mobile DNAPL mass	X	28%	=	22%
90% of mobile DNAPL mass	X	28%	=	25%

(a) HD removes both components of mobile DNAPL, i.e., chlorobenzene and DDT
(b) Mobile mass fraction of the total mass (i.e. 28%) is calculated by dividing the amount of mobile chlorobenzene mass (110,900 lbs) by the total chlorobenzene mass in the entire DNAPL-impacted area (398,100 lbs)

[2] The DNAPL mass estimate used in this evaluation is referred to as the "liberal mass estimate" in other documents and was based on field data and professional judgment.

Thermal Remedy, Entire DNAPL-Impacted Area

In the case of a thermal remedy, two treatment areas were considered; the entire DNAPL-impacted area and a focused treatment area (Earth Tech Case 3) (Attachment A). For treatment in the entire DNAPL-impacted area via ERH or steam injection when 2 to 3 pore volumes of steam are injected, it was assumed that 60, 80, and 90 percent of the initial chlorobenzene mass could be removed. Unlike HD, a thermal technology would only be effective at removing the chlorobenzene component of DNAPL, such that DDT will remain in the subsurface.

While mass removal in excess of 90 percent has been claimed for some sites, there is little empirical support for these mass removal percentages and care must be taken not to base decisions on overly-optimistic or overly-pessimistic performance projections (Kingston, 2008; Kavanaugh and Rao, 2003). The potential effectiveness of thermal remediation in a highly layered aquitard containing an unconventional DNAPL composed of chlorobenzene and DDT is highly uncertain. Given the characteristics of the Montrose Site, e.g., a complex geologic setting, a large volume of saturated soil to be remediated, complex DNAPL composition, and the depth of the treatment zone, we are not aware of any comparable sites where even the percentages assumed for this evaluation have been documented. Nevertheless, for purposes of this evaluation, chlorobenzene mass removal percentages of 60, 80, and 90 percent within the treated area were considered for an ERH remedy or steam injection involving injection of 2 to 3 pore volumes of steam. In fact, removal of 80 to 90 percent of the chlorobenzene mass is considered an optimistic, high-end assumption for mass removal at the Montrose site since no reliable data has been identified to show that these removal percentages have been achievable at a site comparable to the Montrose site.

Thermal Remedy, Focused Treatment Area

Similar to the evaluation of a thermal remedy in the entire DNAPL-impacted area, three mass removal scenarios were considered for ERH or steam with injection of 2 to 3 pore volumes of steam in the focused treatment area, as follows:

Table 2. Thermal Technology Mass Reduction in Focused Treatment Area

Percent Chlorobenzene Mass Reduction in the Focused Treatment Area[a]		**Fraction of Total Mass in the Focused Treatment Area[b]**		**Percent Chlorobenzene Mass Reduction in Entire DNAPL-Impacted Area[a]**
60% of chlorobenzene mass	X	60%	=	36%
80% of chlorobenzene mass	X	60%	=	48%
90% of chlorobenzene mass	X	60%	=	54%

(a) Thermal technologies only remove the chlorobenzene component of DNAPL such that removal percentages represent chlorobenzene mass removal percentages.

(b) The fraction of the total mass in the focused treatment area (i.e. 60%) is calculated by dividing the amount of chlorobenzene mass in the focused treatment area (236,900 lbs) by the total chlorobenzene mass in the entire DNAPL-impacted area (398,100 lbs).

Results

The results for this evaluation are reported in terms of the years required to reach the ISGS of 70 ug/l for chlorobenzene in groundwater following a particular DNAPL remedy, and is referred to as the dissolution timeframe. The average chlorobenzene concentration was computed based on the groundwater flowrate and chlorobenzene mass transiting a cross section of the UBA oriented perpendicular to groundwater flow located immediately downgradient from the source area. Dissolution timeframes for each DNAPL remedial alternative presented below (Table 3) were based on the percentage of chlorobenzene mass reduction relative to the total initial chlorobenzene mass within the entire DNAPL-impacted area. The baseline Containment-Only scenario includes hydraulic containment but no active DNAPL remedy.

Table 3. Results of Modeling Dissolution Timeframes

	Mass Reduction in Treatment Area		**Chlorobenzene Mass Reduction in Entire Area**	**Time to reach ISGS after remedy (years)** Γ **= 1 (First Order Decay)**
Entire DNAPL-Impacted Area				
Containment-Only	0%		0%	4,900
Thermal	60%	Total chlorobenzene in entire DNAPL-impacted area	60%	4,200
	80%		80%	3,600
	90%		90%	3,100
Focused Treatment Area				
Hydraulic Displacement	60%	Mobile chlorobenzene mass in focused treatment area	17%	4,700
	80%		22%	4,700
	90%		25%	4,700
Thermal	60%	Total chlorobenzene mass in focused treatment area	36%	4,500
	80%		48%	4,400
	90%		54%	4,300

Per Table 3, if no DNAPL remedy is performed, the time required to achieve the ISGS for chlorobenzene will be on the order of 4,900 years. Estimated timeframes for dissolution following a HD remedy and a focused thermal remedy are somewhat lower, ranging from about 4,300 to 4,700 years. The estimated timeframes for dissolution following a thermal remedy in the entire DNAPL-impacted area are lower than for a HD remedy or a focused thermal remedy, ranging from about 3,100 to 4,200 years.

Sensitivity Analysis

A sensitivity analysis was conducted to assess the effect of parameter uncertainty on the timeframes estimated during this evaluation. Initially each parameter was evaluated to identify those parameters which had the greatest impact on the timeframe estimates. It was determined that the following five parameters had the greatest impact on the results:

- Empirical Constant, Γ
- Cross-sectional area impacted by DNAPL
- UBA horizontal hydraulic gradient
- UBA hydraulic conductivity
- Initial chlorobenzene mass in the entire DNAPL-impacted area (chlorobenzene mass was varied through the use of several related parameters collectively referred to as "Mass Related Parameters")
- The residual DNAPL saturation (changes in saturation result in changes in the footprint of and mass within the focused treatment area; these parameters are collectively referred to as "Residual Saturation Parameters")

Reasonable minimum and/or maximum values were selected for each parameter based on available Montrose Site data (Attachment A). Figure 2 shows the percentage change in the timeframe required to reach ISGS for chlorobenzene for each parameter, or group of parameters, varied. Based on the results of the sensitivity analysis, the dissolution timeframes could range from minus 76 percent to plus 58 percent of the base case calculated timeframes.

Since the mass estimate utilized in this evaluation has been specifically questioned by EPA, further details are provided below on the impact of the value used for DNAPL mass. For the example provided below, use of a thermal remedy in the entire DNAPL-impacted area is discussed.

Table 4. Example of Sensitivity of Dissolution Timeframe to Mass Estimate

Scenario: Thermal Remedy, entire DNAPL-impacted Area	Base Case Scenario	Upper Bound Scenario (+50%)
DNAPL Mass Estimate	796,100 lbs	1,194,200 lbs
Chlorobenzene Mass Estimate[(a)]	398,100 lbs	597,100 lbs
Timeframe Range	3,100 years to 4,200 years	3,500 years to 4,600 years
Variability from Base Case Scenario	--	+13%

(a) Chlorobenzene mass is half of the DNAPL mass based on site data which indicate that Montrose DNAPL is a 50/50 mixture of chlorobenzene and DDT

Based on the foregoing, this variability in mass considered in this evaluation has limited impact on the estimated timeframes.

Further explanation of the process used for the sensitivity analysis is provided in Attachment A.

Uncertainty

A number of factors contribute to some level of uncertainty in these estimates including DNAPL architecture, site conditions, dissolution dynamics, and back diffusion.

The DNAPL architecture is highly complex[3] at the Montrose Site, which contributes uncertainty to evaluating the impact of source zone remediation on attainment of remedial goals. The combination of complex lithology and variability in other parameters such as soil conductivities and DNAPL saturations, results in uncertainty in the Γ values selected. While site knowledge can be used in combination with perspective provided in Falta, et al. (2005), it is not possible to determine the actual Γ that is applicable to a site, even for sites with simple, homogeneous lithology and DNAPL architecture. This uncertainty is partially addressed by evaluating a range of Γ values as part of the sensitivity analysis.

There is also uncertainty due to the complexity of DNAPL dissolution dynamics and post-remediation equilibrium conditions which would result in a change in DNAPL/plume dynamics. The numerical approach used for estimating dissolution timeframes does not account for all mechanisms that hasten or slow down the dissolution process. For example, for the first few years after a thermal remedy, elevated temperatures in the treatment zone will result in increased chlorobenzene solubility and higher desorption rates, resulting in decreased dissolution timeframes. Dispersion effects would also result in decreased timeframes as groundwater contacting DNAPL in the more upgradient areas of the DNAPL-impacted zone disperses with movement towards the downgradient areas. Conversely, lithologic heterogeneity which results in preferential or non-uniform groundwater flow and dead-end pores would result in decreased dissolution rates, thus resulting in increased dissolution timeframes.

As mentioned earlier, back diffusion is an important process that can sustain plumes long after DNAPL in the source zone has dissolved. Fine-grained low permeability layers can store significant amounts of dissolved phase mass which is released very slowly over time. This can extend the time required to achieve ISGS levels following DNAPL removal. This will in turn extend the operating duration of the hydraulic containment system. Per Dr. Bernie Kueper, back diffusion can be significant in extending times to reach ISGS where dissolution timeframes are less than many hundreds of years, but is not likely a driving factor when considering DNAPL dissolution rates on the order of thousands of years such as those estimated for the Montrose Site.

---

[3] DNAPL at the Montrose Site is distributed in a complex manner typically as residual DNAPL or in thin discontinuous layers or pools ranging from a few inches to several feet in thickness distributed within a heterogeneous sequence of interbedded fine-grained low permeability sands and silts.

Conclusions

The following conclusions can be drawn from the dissolution modeling results:

- The range of potential dissolution timeframes estimated during this evaluation suggests that, using only hydraulic containment, it will take on the order of 4,900 years for the DNAPL within the source area to dissolve to the point where the ISGS for chlorobenzene will be achieved in the UBA.
- Assuming that implementation of a HD remedy removes roughly 60 percent to 90 percent of mobile DNAPL mass, it will take approximately 4,700 years for the DNAPL remaining in the source area to dissolve to the point where the ISGS for chlorobenzene will be achieved.
- An ERH remedy or steam injection with 2 to 3 pore volumes injected in a focused treatment area removing 60 percent to 90 percent of the chlorobenzene mass in the focused treatment area will take on the order of 4,300 to 4,500 years to reach the ISGS for chlorobenzene.
- A thermal DNAPL remedy implemented across the entire DNAPL-impacted area removing 60 percent to 90 percent of the chlorobenzene mass in the entire DNAPL-impacted area will take on the order of 3,100 to 4,200 years to reach the ISGS for chlorobenzene.

Despite the uncertainties, the results presented are reliable estimates and provide a basis for evaluating potential timeframes required to achieve the ISGS for chlorobenzene following certain source depletion remedies. The calculations presented by Falta, et al. (2005) provide a range of estimates, illustrating that DNAPL removal will not materially alter the amount of time required to obtain the ISGS for chlorobenzene, as containment will be required for multiple thousands of years under all scenarios. The estimates presented will facilitate comparison of the various remedial alternatives for effectiveness assessments within the DNAPL FS.

<u>List of Attachments</u>

Table 1 Hydraulic Displacement Mass Reduction (in text table)
Table 2 Thermal Technology Mass Reduction in Focused Treatment Area
Table 3 Results of Modeling Dissolution Timeframes
Table 4 Example of Sensitivity of Dissolution Timeframe to Mass Estimate

Figure 1 Idealized Model of DNAPL Occurrence
Figure 2 Percent Change In Remedial Time Frame for Variations In Parameter Inputs

Attachment A Methodology and Assumptions
Attachment B Dissolution Timeframe Calculations *(Provided on CD only)*

References

EarthTech, 2008. Technical Memorandum Re: DNAPL Focused Treatment Area Evaluation, Saturated Upper Bellflower Aquitard (UBA), Montrose Superfund Site dated June 5, 2008.

Falta, R.W., P.S. Rao, and N. Basu, 2005. Assessing the impacts of partial mass depletion in DNAPL source zones. I. Analytical modeling of source strength functions and plume response. Journal of Contaminant Hydrology, 78, 259-280.

Hargis + Associates, Inc., 1999. <u>Dense Non-Aqueous Phase Liquid Feasibility Study, Montrose Site, Torrance, California</u>. September 28, 1999.

_____, 2004. <u>Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, California, Revision 1.0</u>. October 22, 2004.

_____, 2007. Email to J. Dhont, EPA, re DNAPL Thickness Map, dated December 20, 2007.

_____, 2008. Email to J. Dhont, EPA, re DNAPL Thickness Map, dated January 22, 2008.

Kavanaugh, M.C. and P.S.C. Rao, Co-Chairs, 2003. “The DNAPL Remediation Challenge: Is There a Case for Source Depletion?”, EPA/600/R-03/143, December 2003

Kingston, J.L.T., 2008. A Critical Evaluation of In-Situ Thermal Technologies. A Dissertation Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy, Arizona State University, May 2008.

Newell, C.J. and D.T. Adamson, 2005. Planning-level source decay models to evaluate impact of source depletion on remediation time frame. Remediation, Autumn 2005, 27-47.

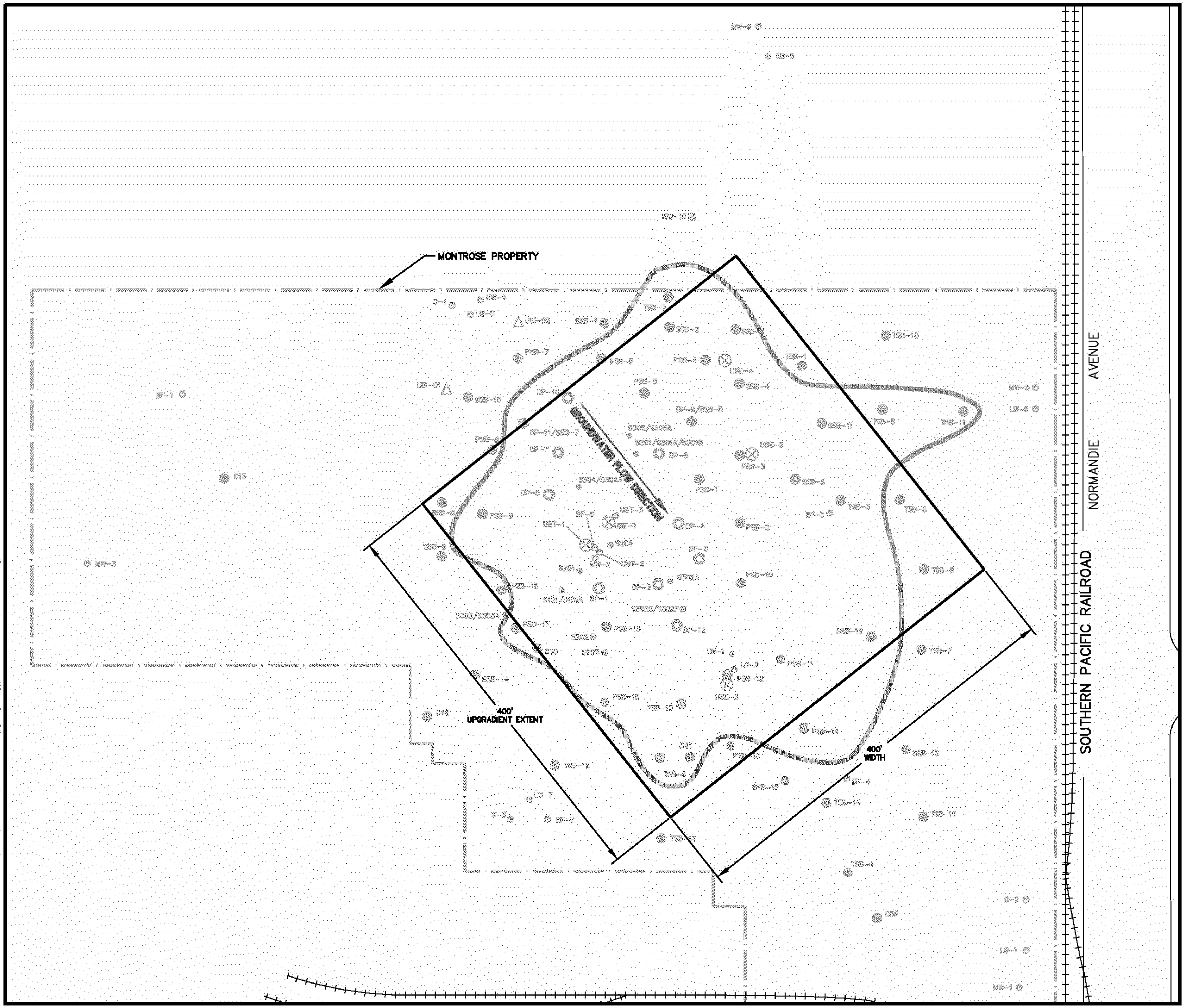
Parker, J.C. and E. Park, 2004. Modeling field-scale dense nonaqueous phase liquid dissolution kinetics in heterogeneous aquifers. Water Resources Research, 40, W05109.

U.S. Environmental Protection Agency, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. 1988.

_____, 1999. Record of Decision for Dual Site Groundwater Operable Unit, Montrose Chemical and Del Amo Superfund Sites. March 1999.

_____, 2008a. http://www.clu-in.org/conf/t10/toolkitdnapl_020508/. DNAPL Source Zones, Mark L. Brusseau, University of Arizona. February 5, 2008.

_____, 2008b. Letter to J. Kelly, Montrose from J. Dhont, Re: EPA Comments on Containment Zone Timeframes Technical Memorandum; Montrose Chemical Superfund Site, Los Angeles County, CA. December 23, 2008.



EXPLANATION

S305/S305A	SOIL BORING
MW-2	MONITOR WELL
PSB-7	SONIC BORING
DP-10	DIRECT PUSH BORING
UBE-2	EXTRACTION WELL
UBI-01	INJECTION WELL
	PROPERTY BOUNDARY
	APPROXIMATE EXTENT OF OBSERVED DNAPL BELOW THE WATER TABLE
	IDEALIZED MODEL OF AREAL EXTENT OF DNAPL 400ftx400ft

NOTE: OBSERVED DNAPL EXTENT BASED ON DATA COLLECTED AS PART OF THE SUPPLEMENTAL SOILS INVESTIGATION IN A TECHNICAL MEMORANDUM TITLED: DNAPL RECONNAISSANCE BORINGS IN SUPPORT OF EARTH TECH SOIL SAMPLING PROGRAM. MONTROSE SITE TORRANCE, CALIFORNIA JANUARY 19, 2006

N

0 100 200

FEET

MONTROSE CHEMICAL CORPORATION
OF CALIFORNIA
TORRANCE, CALIFORNIA

IDEALIZED MODEL OF DNAPL OCCURRENCE

HARGIS+ASSOCIATES, INC.
Hydrogeology/Engineering

02/09

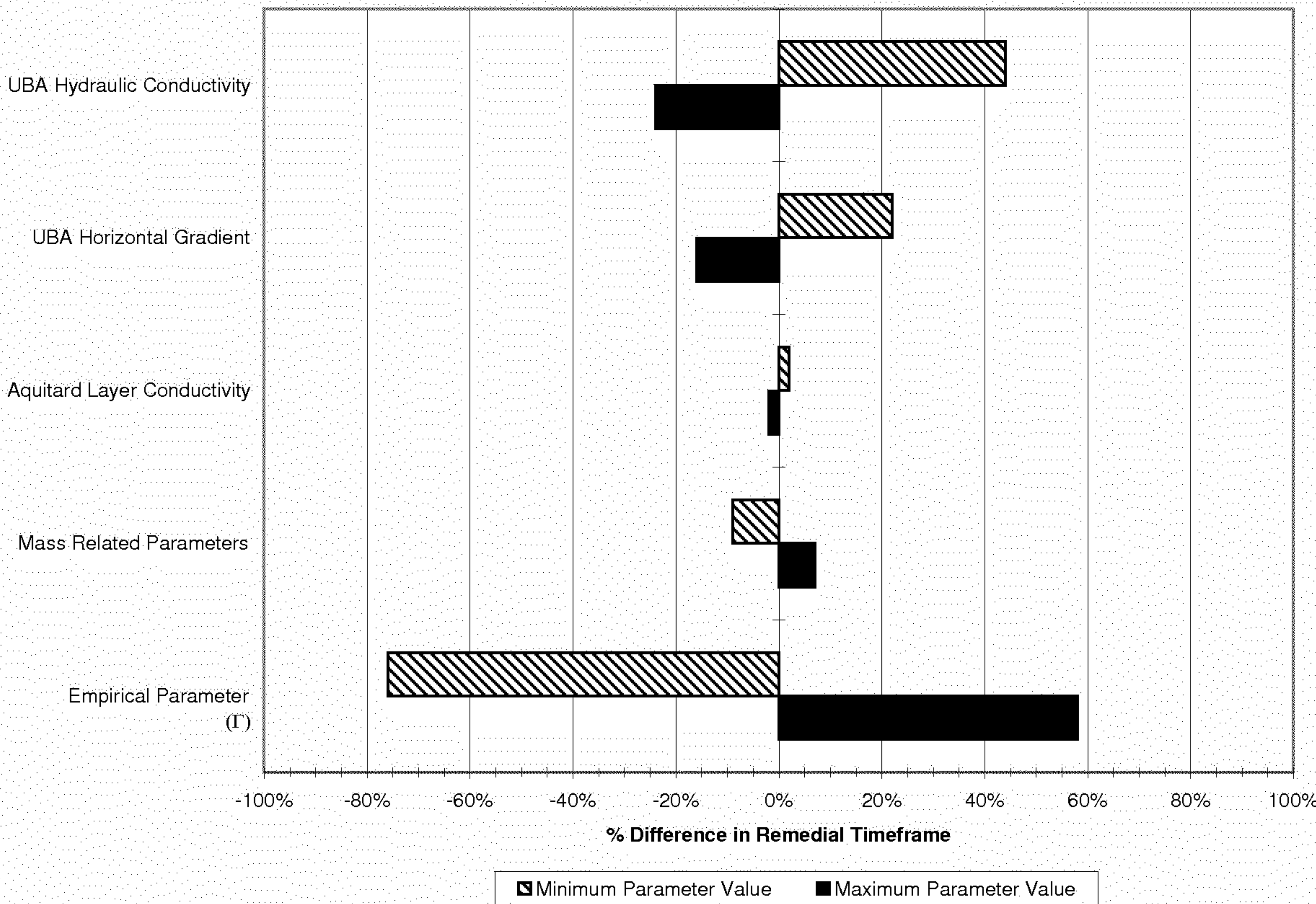
FIGURE 1

PREP BY RDC REV BY DMO RPT NO. 857.04C | 410-7048 | A

Feb 06, 2009 - 9:56am GTH - T:\2009\800-899\857 Montrose\Hydrogeology\H+A BaseMaps\410-7048.dwg

BOE-C6-0060042

Figure 2. Percent Change In Remedial Timeframe for Variations In Parameter Inputs



857 TM01A Fig 2.xls
03-25-09

ATTACHMENT A

METHODOLOGY AND ASSUMPTIONS

ATTACHMENT A
METHODOLOGY AND ASSUMPTIONS

This attachment presents the methodology and assumptions that were utilized in estimating the time required to achieve the in-situ groundwater standard (ISGS) for chlorobenzene of 70 micrograms per liter (ug/l) following a potential dense non-aqueous phase liquid (DNAPL) remedy at the Montrose Chemical Corporation of California (Montrose) site in Torrance, California. DNAPL presence has been confirmed the saturated portion of the UBA at the Montrose Property to a depth of about 100 feet below land surface (bls) (Hargis + Associates, Inc. [H+A], 2004). Since the base of the upper Bellflower aquitard (UBA) is encountered at about 105 feet bls in this area, confirmed DNAPL evidence is limited to the UBA. Thus, this analysis solely focuses on DNAPL in the UBA and does not address the affect on containment timeframes for DNAPL that may be present in the underlying Bellflower Sand (BFS).

This attachment presents the following: (1) modeling approach (2) site conditions and input parameter assumptions, and (3) sensitivity of results to parameter uncertainty.

APPROACH

A number of analytical solutions have been published for estimating timeframes for DNAPL source depletion (Newell and Adamson, 2005; Falta et al., 2005). Generally, these solutions are based on mass-balance calculations that relate changes in DNAPL source mass to changes in the dissolved groundwater concentrations and/or mass emanating from the source zone. The basic form of the mass-balance calculations assumes that for a given DNAPL compound, the ratio of the dissolved groundwater concentration at any point in time to the initial groundwater concentration is related to the ratio of the remaining DNAPL mass, to the initial DNAPL mass, by the following equation:

$$\frac{C}{C_0} = \left(\frac{M}{M_0}\right)^{\Gamma} \qquad \text{Power Relationship} \qquad (1)$$

C = Concentration, dissolved phase in groundwater (C_0 is the initial concentration)
M = Mass (M_0 is the initial mass)
Γ = Empirical parameter

The empirical parameter Γ is related to the DNAPL architecture, which incorporates both the distribution of DNAPL within the zone and the soil and aquifer properties of the DNAPL zone. As described in Falta, et al. (2005), lower Γ values, on the order of 0.5 or less, are typical of source zones where DNAPL resides in highly permeable soils, with DNAPL distributed in large horizontal pools. Higher Γ values, on the order of 2.0, are typical of heterogeneous source zones or where DNAPL is distributed in lower permeability soils.

In the case of Γ = 1, the power equation becomes equivalent to the first-order decay equation described by Newell et al. (2005), and the concentration ratio decreases at the same rate as the mass ratio. In this case it is assumed that at all times the reduction in the groundwater concentration is directly proportional to the reduction in the DNAPL mass.

Power Function Model

The power relationship shown in Equation (1) describes the relationship between dissolved phase concentration and DNAPL mass, but does not provide information on how the mass is expected to decline over time under the process of DNAPL dissolution. The power function model utilizes two solutions that describe the behavior of mass and concentration as a function of time according to the power relationship described in Equation (1). Falta, et al. (2005) derived analytical solutions shown in Equations (2) and (3) for cases when DNAPL source mass is only removed by dissolution:

$$C_s(t) = \frac{C_0}{M_0^{\Gamma}}\left\{\frac{(\Gamma-1)V_d A C_0}{M_0^{\Gamma}}t + M_0^{1-\Gamma}\right\}^{\frac{\Gamma}{1-\Gamma}} \qquad (2)$$

$$M(t) = \left\{\frac{(\Gamma-1)V_d A C_0}{M_0^{\Gamma}}t + M_0^{1-\Gamma}\right\}^{\frac{1}{1-\Gamma}} \qquad (3)$$

$C_s(t)$ = Source zone concentration as a function of time, dissolved phase in groundwater
C_0 = Initial concentration
$M(t)$ = Source zone DNAPL mass as a function of time
M_0 = Initial mass
Γ = Empirical parameter
V_d = Darcy velocity
A = Cross-sectional area of groundwater flow
t = time

The starting mass, M_0, is defined by site characteristics. A mass loading goal is defined for this analysis as the ISGS multiplied by the groundwater flow rate; the groundwater flow rate is the rate of groundwater movement through the downgradient cross-sectional area. The remedial timeframe is the calculated timeframe to reach the ISGS following DNAPL remediation.

It is important to note that Equations (2) and (3) can not be solved for $\Gamma = 1$, representing the first-order decay function; however, this case can be evaluated by setting Γ equal to a value approaching one such as $0.999\overline{9}$.

Equation (2) was rearranged to solve for time to reach an ISGS concentration when DNAPL source mass is only removed by dissolution for all power function cases where Γ is not equal to 1, as follows:

$$t = \left[\left(\frac{C_s(t)M_0^{\Gamma}}{C_0}\right)^{\frac{1-\Gamma}{\Gamma}} - M_0^{1-\Gamma}\right]\frac{M_0^{\Gamma}}{(\Gamma-1)V_d A C_0} \qquad (4)$$

The various terms of this equation are as defined for Equations (2) and (3).

To account for partial depletion of the source mass by a DNAPL remedy, Falta, et al. (2005) offers two additional equations:

$$M_t = (1 - X)M_0 \qquad (5)$$

M_0 = Initial mass
M_t = Mass following source reduction activities
X = Fraction of the initial mass removed by source reduction activities

$$C_t = C_0\left(\frac{M_t}{M_0}\right)^{\Gamma} \qquad (6)$$

C_0 = Concentration, dissolved phase in groundwater prior to source reduction activities
C_t = Concentration, dissolved phase in groundwater following source reduction activities
M_0 = Initial mass
M_t = Mass following source reduction activities
Γ = Empirical parameter

Equation (4) can be solved for the time to reach an ISGS concentration when DNAPL source mass is removed by source reduction activities for all power function cases where Γ is not equal to 1 by replacing the initial mass term (M_0) with the equation for M_t (Equation 5) and by replacing the initial concentration term (C_0) with the equation for C_t (Equation 6), as follows:

$$t = \left[\left(\frac{C_s(t)M_t^{\Gamma}}{C_t}\right)^{\frac{1-\Gamma}{\Gamma}} - M_t^{1-\Gamma}\right]\frac{M_t^{\Gamma}}{(\Gamma - 1)V_d A C_t} \qquad (7)$$

The various terms of this equation are as defined for Equations (3), (5), and (6).

SITE CONDITIONS AND INPUT PARAMETER ASSUMPTIONS

The mass balance models generally require the following inputs:

- the initial chlorobenzene mass associated with the DNAPL;
- the amount of chlorobenzene mass reduction achieved by the DNAPL remedy; and
- the target chlorobenzene mass, which is analogous to the ISGS chlorobenzene concentration.

In order to develop the input parameters for the models, data from the 1999 Draft DNAPL Feasibility Study (H+A, 1999), the DNAPL extraction test (H+A, 2007), and the groundwater model developed by the U.S. Environmental Protection Agency (EPA) for the groundwater Remedial Design (CH2M Hill, 2008), were combined to estimate parameters specific to the Montrose Site. Other sources of data are cited below, as appropriate. Assumed parameter values are provided in Table A-1 and depicted in Figure A-1. The basis for the parameter values selected is presented in the following section.

DNAPL-Impacted Area

The aerial extent of DNAPL, approximately 162,000 square feet (ft^2), was calculated by mapping the estimated DNAPL extent from boring logs. This area is referred to as the entire DNAPL-impacted area.

A second treatment area, referred to as the focused treatment area, is also considered as part of this evaluation. The focused treatment area is delineated by the extent of mobile DNAPL mass which is defined by areas where the DNAPL saturation exceeds the residual saturation. The focused treatment area is described as Case 3 in the EarthTech memorandum dated June 5, 2008 (EarthTech, 2008a). Since hydraulic displacement (HD) is only capable of removing mobile DNAPL mass, the focused area is the only scenario considered. For a thermal remedy, both the entire DNAPL-impacted area and the focused treatment are considered.

When the focused treatment area is considered, mass is only actively removed by the remedy from the treatment area; dissolution is then evaluated for the mass outside of the treatment area and the mass remaining inside the treatment area not recovered by the active remedy.

DNAPL Thickness and Cross-Sectional Area

DNAPL is known to be distributed unevenly throughout the UBA. Where DNAPL comes in contact with groundwater, chlorobenzene dissolves, resulting in concentrations approaching the solubility limit. However, the chlorobenzene concentration may not be detectable in areas of the UBA where groundwater does not contact DNAPL. In order to estimate the average chlorobenzene concentration and mass passing through a cross section of the UBA downgradient of the DNAPL source area, the cross-sectional area of the UBA where groundwater contacts DNAPL was estimated. To accomplish this, the DNAPL source was conceptualized as a single, bell-shaped layer that extends across an idealized 400 by 400 square foot source area (Figure A-1). The bell shape of the DNAPL layer results from the spatial and vertical distribution of the DNAPL. The area of this curve, in profile, represents the cross-sectional area of the UBA where groundwater will come in contact with DNAPL The bulk of the DNAPL exists in the core of the DNAPL-impacted area, represented by the center, thickest part of the bell curve. The DNAPL diminishes away from the main source area, represented by the decreasing thickness approaching the edge of the DNAPL-impacted area.

The thickness of the DNAPL(i.e. the vertical distribution) was evaluated by considering the thickness of DNAPL within individual borings. The thickness estimates used in this evaluation were developed using data collected during the DNAPL reconnaissance program and from other historic soil borings (H+A, 2004; EPA, 1998). DNAPL evidence, including visual observation, staining on Flexible Liner Underground Technology (FLUTe) ribbon, soil core analytical data, and organic vapor measurements, were used to estimate DNAPL thickness. DNAPL evidence was used in combination with soil lithology to develop an estimate of DNAPL thickness in the individual borings (H+A, 2008a; EarthTech, 2008a).

The thickness data was kriged to generate a set of thickness contours. The contours were then used to evaluate the thickness data in profile to develop the bell-shaped distribution of DNAPL across the DNAPL-impacted area, as conceptualized in Figure A-1.

Chlorobenzene Mass

The Montrose DNAPL is an approximate 50/50 mixture of chlorobenzene and DDT. However, for the purposes of evaluating timeframes required to achieve the ISGS for chlorobenzene, the mass of the chlorobenzene component is more pertinent to this evaluation. Further, the two technologies considered in this evaluation (i.e., HD and thermal technologies) remove mass differently. While HD will remove both the chlorobenzene and DDT component of the DNAPL, it can only remove mobile DNAPL mass such that it is necessary to understand the amount of DNAPL mass that exceeds the residual saturation value and is therefore potentially mobile. Thermal technologies are capable of removing both mobile and immobile chlorobenzene mass. They are not, however, capable of removing the DDT component of the DNAPL which would be left in an immobile, almost insoluble form in the subsurface.

The total initial DNAPL mass in the DNAPL-impacted area was calculated as the product of (i) the thickness of soil with confirmed DNAPL-impact; (ii) the concentration of intervals with confirmed DNAPL-impact; (iii) the treatment area; and (iv) the wet bulk density (EarthTech, 2008a) (Table A-2). The same approach for calculating mass (Earth Tech 2008a) was applied using only those borings which are within the focused treatment area to estimate the mass DNAPL in the focused treatment area (Table A-3). The approximate mass of mobile DNAPL was calculated similarly (Table A-4). Mobile DNAPL is associated with soil containing DNAPL in excess of the residual saturation of 19% which is equivalent to a DNAPL concentration of approximately 53,000 milligrams per kilogram (mg/kg). Thus, only the amount of mass associated with the portion of the concentration in excess of 53,000 mg/kg was used to calculate mobile mass (Table A-4). The estimates of DNAPL mass and the chlorobenzene mass associated with the DNAPL, are summarized below in Table A-5.

Table A-5. Estimates of DNAPL Mass

Description	DNAPL Mass (lbs)	**Chlorobenzene Mass[(a)] (lbs)**
Total Mass, entire DNAPL-impacted area	796,100	**398,100**
Total Mass, focused treatment area	473,700	**236,900**
Mobile Mass	221,800	**110,900**

(a) = the chlorobenzene mass is half of the DNAPL mass based on the approximate 50/50 ratio of chlorobenzene and DDT in the Montrose DNAPL

Horizontal Groundwater Flow

In this analysis, both the components of horizontal groundwater flow within the UBA and vertical groundwater flow from the UBA to the BFS, as depicted in Figure A-1, were calculated in order to estimate the combined DNAPL mass loading. Calculations are based on the following assumptions:

- The average saturated thickness is 40 feet. This was based on the vertical interval from the water table at about 60 feet bls to the maximum depth of confirmed DNAPL of about 100 feet bls, as reported during the DNAPL reconnaissance investigation (H+A, 2004).
- The average horizontal hydraulic conductivity, K_h, of the UBA was determined from transmissivities calculated during extraction testing of on-Property UBA wells UBE-1 and UBT-1 during the DNAPL extraction testing (H+A, 2007). The time-drawdown data collected during short-duration DNAPL extraction testing at these two wells yielded transmissivity values of 4,500 gallons per day per foot (gpd/ft) or about 600 square feet per day (ft^2/day) (H+A, 2007). The average K_h of the UBA was estimated by dividing the UBA transmissivity by the average thickness of 40 feet, resulting in an estimated K_h of 15 feet per day (ft/day).
- The horizontal hydraulic gradient in the UBA in the vicinity of the DNAPL source area was calculated based on a steady state simulation using the calibrated groundwater Remedial Design model assuming only the hydraulic containment wells are pumping. A water level contour figure based on the model simulation was prepared and the horizontal gradient on the Montrose Property was estimated based on the spacing of the water level contours (Figure A-2). The groundwater Remedial Design model results indicate that the horizontal gradient at the site would be approximately 0.0025 in the UBA under a hydraulic containment scenario.
- The flow rate of groundwater passing through a cross-sectional area 400 feet wide and 40 feet thick was calculated using Darcy's Law:

$$Q = K \times I \times A \qquad (8)$$

Q = the groundwater flow rate
K = hydraulic conductivity
I = hydraulic gradient, and
A = the cross-sectional area

Based on the forgoing, the horizontal groundwater flow rate is estimated to be approximately 600 cubic feet per day (ft^3/day).

<u>Average Chlorobenzene Concentration in UBA Groundwater</u>

The initial average chlorobenzene concentration in the UBA downgradient from the source zone was estimated by applying a mixing model within the vertical section of the UBA. The mixing model assumes that the chlorobenzene concentration in groundwater contacting DNAPL is equal to the theoretical maximum concentration of chlorobenzene in groundwater or, the multi-component solubility limit of chlorobenzene of approximately 410,000 ug/l (EPA, 1998). This concentration is applied to the cross-sectional area where groundwater contacts DNAPL (i.e., the bell-shaped curve described above). The mixing model also assumes that groundwater from the DNAPL zone at this maximum concentration would mix with groundwater containing no chlorobenzene throughout the remainder of the UBA as the plume leaves the source area. Therefore, the average chlorobenzene concentration can be calculated by dividing the total mass loading by the total groundwater flow rate and performing the appropriate unit conversions. Since the concentration of chlorobenzene in the non-DNAPL zone is assumed to be zero, the total mass loading is equal to the mass loading from the DNAPL-impacted zone. This results in an average chlorobenzene concentration of approximately 33,700 ug/l in the UBA.

Vertical Groundwater Flow

Calculations for estimating downward flow rate of groundwater from the DNAPL source area in the UBA to the BFS are based on the following assumptions:

- The cross-sectional area supporting vertical flow was assumed to be equal to the aerial extent of the DNAPL source zone of approximately 162,000 ft^2.
- The head difference across the lower portion of the UBA was calculated from the groundwater Remedial Design model hydraulic containment simulation results, described above. Based on this simulation, the water level difference between the UBA and BFS in the vicinity of the DNAPL source area would be about 0.3 foot with only the hydraulic containment wells operating. The estimated thickness of the aquitard sediments separating the DNAPL zone from the BFS was determined from lithologic logs from borings S301A, S302A, S304A, and S305A in the area of DNAPL impact (H+A, 1988). The thickness of the basal fine-grained aquitard sediments that exist between the DNAPL-impacted zone and the BFS were assumed to control the vertical flow of groundwater to the BFS in this area. The thickness of the aquitard sediments in these four borings ranged from 8.5 to 13.5 feet, and the average thickness is 10.75 feet. Therefore, an aquitard thickness of 11 feet was used for the calculation of vertical flow through the basal silty sand sediments.
- The average vertical hydraulic gradient across the silty aquitard sediments was computed as the head difference of 0.3 foot divided by the unit thickness of 11 feet which results in a vertical hydraulic gradient of 0.027.
- The vertical hydraulic conductivity of the aquitard sediments was assumed to be equal to the geometric mean of vertical hydraulic conductivities measured for fine-grained soil samples collected from the UBA by Earth Tech (2008b) and fine-grained off-Property soil samples collected from the UBA (EPA, 1998). Based on the foregoing, the average vertical conductivity is approximately 4.9×10^{-3} ft/day.

The vertical groundwater flow rate passing through the cross-sectional area of the DNAPL-impacted zone was calculated using Darcy's Law (Equation 8), as described above. Based on the forgoing, the vertical groundwater flow rate is estimated to be approximately 21.4 ft^3/day.

Chlorobenzene Mass Loading

The chlorobenzene mass loading is calculated as the total loading out of the UBA in both the horizontal and vertical direction.

Horizontal Component

The initial average chlorobenzene mass loading from the source area was calculated based on the groundwater flow rate and average chlorobenzene concentration as described above. Based on an average chlorobenzene concentration of about 33,700 ug/l, a groundwater flow rate in the conceptualized DNAPL layer of 49.3 ft^3/day, and accounting for unit conversions, yields a horizontal mass loading of 357 pounds per year (lbs/year) emanating from the DNAPL source area.

Vertical Component

The vertical mass flow rate of chlorobenzene from the source area into the BFS was calculated based on the vertical groundwater flow rate and average chlorobenzene concentration in the UBA, as described above. Based on an average chlorobenzene concentration of 100,000 ug/l from recently collected depth discrete data from the BFS (H+A, 2008b) and accounting for unit conversions, a groundwater flowrate of 21.4 ft^3/day, and accounting for unit conversions, yields a vertical chlorobenzene mass loading of 48.7 lbs/year emanating vertically from the DNAPL source area.

Chlorobenzene Mass Reduction by a DNAPL Remedy

In order to estimate dissolution timeframes for the different DNAPL remedial technologies, it is necessary to include assumptions for the percent of chlorobenzene mass reduction that is likely to be achieved with each technology. The selected DNAPL remedy may include one of two active DNAPL remediation approaches: HD or a thermal technology. For a thermal technology, two treatment areas are considered: the entire DNAPL-impacted area and a focused treatment area. For the HD remedy, only the focused treatment area is considered. The focused treatment area is equivalent for both technologies and is defined by the extent of mobile DNAPL mass; this area is referred to as Case #3 in a June 5, 2008 EarthTech memorandum (EarthTech, 2008a). Furthermore, in all cases, mass reduction percentages discussed below refer to reductions relative to the initial chlorobenzene mass within the entire DNAPL-impacted area.

Hydraulic Displacement Remedy

DNAPL is potentially mobile at saturations exceeding the residual saturation. If effectively implemented, HD can reduce DNAPL saturations to nearly the residual saturation. An average residual saturation value of 0.19 used for this evaluation was based on a DNAPL-water capillary pressure curve developed based on a soil sample from the UBA at the Montrose Site (EarthTech, 2008b). This is equivalent to a DNAPL concentration (i.e., chlorobenzene plus DDT) of approximately 53,000 mg/kg (Earth Tech 2008a). Thus, it was assumed that for HD to remove DNAPL, the DNAPL concentration must exceed approximately 53,000 mg/kg. As described above, the amount of chlorobenzene mass associated with the mobile DNAPL at the site is estimated to be 110,900 lbs, or approximately 28 percent of the total chlorobenzene mass associated with DNAPL in the entire DNAPL-impacted area. This is the theoretical maximum chlorobenzene mass that could be removed by HD.

For the purposes of this evaluation, mass removal percentages of 60, 80, and 90 percent of mobile mass were utilized for HD. The percentage of mobile DNAPL that can be recovered using HD at the Montrose site was based on DNAPL/water capillary pressure testing conducted on the Montrose DNAPL as well as published information about other sites (Sale, et al, 1997; Gerhard, et al, 2001). As described further in the upcoming DNAPL FS Report, DNAPL/water capillary pressure testing indicates that while it is unlikely that HD will recovery 100 percent of the mobile DNAPL, removal efficiencies on the order of 80 to 90 percent are considered reasonable. Investigations at other sites further support the recovery efficiencies utilized. One full-scale site utilizing horizontal drains was reported to have achieved approximately 95 percent mobile mass removal (Sale, et al, 1997). Per Dr. Bernie Kueper, information presented in a modeling study conducted to evaluate a potential

DNAPL HD remedy at another site (Gerhard, et al, 2001) indicates that about 75 percent of the mobile DNAPL mass could be recovered using horizontal wells.

Since approximately 28 percent of the total chlorobenzene mass is potentially mobile, mass removal percentages of 60, 80, and 90 percent are equivalent to removal of 17, 22, and 25 percent removal of the total chlorobenzene mass in the entire DNAPL-impacted area.

Thermal Remedy

Thermal remedies have been employed at pilot- and full-scale at more than 180 sites nationally. Mass reductions of greater than 90 percent have been claimed for a number of projects; however, a recent extensive analysis of thermal sites concluded that "the long term effect on groundwater quality improvements and source discharge reductions appear to be poorly documented and/or not monitored at many thermal sites" (Kingston, 2008). Moreover, an EPA report prepared by Kavanaugh and Rao, (2003), points out that reduction claims are inherently inaccurate due to the uncertainty of estimating the initial mass of DNAPL prior to source removal. Thus, there is little empirical support for the prior estimates of mass removal percentages and care must be taken not to base decisions on overly-optimistic or overly-pessimistic performance projections. Given: 1) the complex geologic setting with pooled DNAPL located in a highly layered and heterogeneous aquitard of 40 or more feet in thickness underlain by a sandy aquifer, 2) the large volume of saturated soil to be remediated, 3) the complex DNAPL composition which includes a large percentage of DDT, a non-volatile organic solid, and 4) the depth of treatment zone, we are not aware of any comparable site where the percentages employed in this report have been documented.

Nevertheless, for purposes of this evaluation, chlorobenzene mass removal percentages of 60, 80, and 90 percent within the treated area were considered for an electrical resistance heating (ERH) remedy or steam injection remedy involving injection of 2 to 3 pore volumes of steam.

There is approximately 237,000 lbs of chlorobenzene mass in the focused treatment area or, about 60 percent of the total chlorobenzene mass in the entire DNAPL-impacted area. Thus, removal of 60, 80, and 90 percent of the total chlorobenzene mass in the focused treatment area is equivalent to removal of 36, 48, and 54 percent of the total chlorobenzene mass in the entire DNAPL-impacted area.

Hydraulic Containment Only

In addition, a hydraulic containment only scenario was evaluated where there was no active DNAPL remediation and therefore no initial source depletion associated with an active DNAPL remedy.

PARAMETER UNCERTAINTY – SENSITIVITY ANALYSIS

In order to assess the potential effects of parameter uncertainty on the evaluation results, a sensitivity analysis was performed. Prior to conducting the sensitivity analysis, all parameters were screened to identify which were likely to have the greatest effect on the results. Certain parameters were considered fixed values such as the width of the DNAPL zone, the thickness of the UBA, and the maximum concentration of chlorobenzene in groundwater. Other parameters were found to have minimal effect on the calculated dissolution timeframes including the hydraulic conductivity and the gradient in the aquitard separating the UBA and the BFS. The following section presents the sensitivity analysis results for the parameters which have the greatest effect on the dissolution timeframes. Parameter ranges used during the sensitivity analysis are presented in Table A-1. Results of the sensitivity analysis are shown graphically in Figure 2 and are presented in terms of percent difference in the dissolution timeframe where a positive percentage indicates an increase in the timeframe and a negative percentage indicates a decrease in the timeframe.

Horizontal Gradient and Hydraulic Conductivity in the UBA

The dissolution timeframe is inversely proportional to the horizontal hydraulic gradient and K_h of the UBA, which are components of the calculation of the groundwater flow rate and therefore also components of mass loading.

During the sensitivity analysis the horizontal hydraulic gradient in the UBA was varied by a factor of ±20 percent to provide a range of values that may occur under actual conditions. This is consistent with the range of values predicted by the calibrated groundwater Remedial Design model under the containment scenario, or 0.0025 to 0.003 in the UBA. This resulted in a variation in the dissolution timeframe of up to 22 percent.

During the sensitivity analysis the horizontal hydraulic conductivity of the UBA was varied from by a factor of about ±30 percent, i.e., from 10 to 20 ft/day, which resulted in a variation in the dissolution timeframe of up to 44 percent.

Cross-Sectional Area of DNAPL Impact and Total Initial Chlorobenzene Mass

There are several parameters that are directly linked to the total initial DNAPL mass in the entire DNAPL-impacted area, including:

- Cross-sectional area of the conceptual bell-shaped DNAPL layer (see above discussion of “DNAPL Thickness and Cross-Sectional Area”)
- Initial mass of chlorobenzene in the entire DNAPL-impacted area
- Initial mass of chlorobenzene and mobile chlorobenzene in the focused treatment area

These input parameters are collectively referred to as “Mass Related Parameters” and were varied together in the sensitivity analysis to evaluate the uncertainty associated with the DNAPL mass estimates. As part of the sensitivity analysis, the base-case values for the cross-sectional area and the initial mass values were increased by 50 percent, as shown below.

Table A-6. Sensitivity Analysis of Mass-Related Parameters

Input Parameter	**Base Case Value**	**Upper Bound Value**
Cross-Sectional Area	1,314 ft^2	1,971 ft^2
Total MCB Mass, Entire DNAPL-impacted Area	398,100 lbs	597,100 lbs

MCB = chlorobenzene

An increase in initial mass of 50 percent was utilized since it is consistent with the high end of the range considered appropriate for Feasibility Level cost estimates. In both the base case and the upper bound of the sensitivity analysis, 60 percent of the total chlorobenzene mass is in the focused treatment area and 28 percent of the total chlorobenzene mass is mobile.

This adjustment resulted in a variation in the dissolution timeframe of up to 9 percent.

Residual DNAPL Saturation

There are several parameters that are directly linked to the DNAPL residual saturation including:

- Foot-print of the focused treatment area
- Initial mass of chlorobenzene in the focused treatment area
- Initial mass of mobile chlorobenzene in the focused treatment area

These input parameters are collectively referred to as “Residual Saturation Parameters” and were varied together in the sensitivity analysis to evaluate the uncertainty associated with the DNAPL residual saturation.

The average residual saturation value of 0.19 used for this evaluation was based on a DNAPL-water capillary pressure curve developed based on a soil sample from the UBA at the Montrose Site (EarthTech, 2008b). Residual saturation is, however, a function of a number of variables including the lithology within which the DNAPL is present and the initial amount of DNAPL present at a particular location. Thus, the measured residual saturation of 0.19 may not be applicable to all DNAPL pools. Per Dr. Bernie Kueper, the residual saturation is not likely to be lower than the value determined based on the laboratory analysis (Earth Tech, 2008b); however, it could range as high as 0.25. This is equivalent to a DNAPL concentration (i.e., chlorobenzene plus DDT) of approximately 70,000 mg/kg (Earth Tech 2008a). A focused treatment area defined by a soil concentration of 70,000 mg/kg encompasses a smaller area than the area defined by a soil concentration of 53,000 mg/kg (i.e. a residual saturation of 0.19). This is because fewer borings have soil concentrations in excess of the higher threshold. The smaller footprint of the focused treatment area contains less total mass and less mobile mass, as indicated below.

Table A-7. Sensitivity Analysis of Residual Saturation Parameters

Input Parameter	**Value When Residual Saturation 19%**	**Value When Residual Saturation 25%**
Footprint of Focused Treatment Area	26,000 ft^2	18,100 ft^2
Total MCB Mass in Focused Treatment Area(a)	236,900 lbs (60%)	190,800 lbs (48%)
Mobile MCB Mass in Focused Treatment Area(a)	110,900 lbs (28%)	85,000 lbs (21%)

(a) = value in parenthetical represents the fraction of the total MCB mass in the entire DNAPL-impacted area which is present in the focused treatment area
MCB = chlorobenzene

This adjustment resulted in a variation in the dissolution timeframe of up to 4 percent. It should be noted that only timeframes for treatment scenarios associated with the focused treatment area are impacted by a change in the residual saturation since a change in the residual saturation does not result in a change in the total mass in the entire DNAPL-impacted area.

Aquitard Vertical Conductivity

The vertical hydraulic conductivity of the aquitard sediments was estimated to be 4.9×10^{-3} ft/day, as described above. During the sensitivity analysis, the vertical hydraulic conductivity of the aquitard sediments was varied by a factor of ± 20 percent, i.e. from 3.9×10^{-3} to 5.9×10^{-3}. This resulted in a variation in the dissolution timeframe of up to 2 percent.

Empirical Parameter, Γ

The power function model used to estimate dissolution timeframes in this evaluation includes an empirical parameter, Γ, which is selected based on site characteristics. For this evaluation, a conservative, base case Γ value of 1 was used. This represents a commonly assumed median approach for NAPL sites (Newell & Adamson, 2005; Falta, et al., 2005; Parker and Park, 2004) and, based on direct communication with Dr. Ronald Falta, a gamma value of near 1 is common based on analysis of field and laboratory data. In order to evaluate the sensitivity of the estimated timeframe to a range of potential Γ values, the empirical parameter was varied between 0.6 and 1.2. This resulted in a variation in the dissolution timeframe of up to 76 percent.

Lower Γ values, on the order of 0.5 or less, are typical of source zones where DNAPL tends to reside in high permeability soils and with DNAPL distributed in large horizontal pools. Higher Γ values on the order of 2.0 are typical of heterogeneous source zones where DNAPL is distributed in lower permeability soils. The lithology and DNAPL distribution at the Montrose Site is indicative of Γ values that are greater than 1. The UBA consists of a heterogeneous sequence of interbedded fine-grained low permeability sands and silts. Furthermore, the DNAPL is distributed in a complex manner typically as thin discontinuous layers ranging from a few inches to several feet in thickness.

List of Attachments

REFERENCES

CH2M Hill, 2008. Model Development and Remedial Wellfield Optimization Report, Dual Site Groundwater Operable Unit Remedial Design, Montrose chemical and Del Amo Superfund Sites. September 2008.

EarthTech, 2008a. Technical Memorandum Re: DNAPL Focused Treatment Area Evaluation, Saturated Upper Bellflower Aquitard (UBA), Montrose Superfund Site dated June 5, 2008.

______, 2008b. Email from B. Dean to D.Ondic, H+A, Re: Montrose Torrance DNAPL – 2D Study Baseline Physical Property Results, dated June 30, 2008.

Falta, R.W., P.S. Rao, and N. Basu, 2005. "Assessing the impacts of partial mass depletion in DNAPL source zones. I. analytical modeling of source strength functions and plume response". Journal of Contaminant Hydrology, 78 (2005) pp 259-280. 2005

Hargis + Associates, Inc., 1988. Field Data Submittal, Part 2, Remedial Investigative Work, Phase 2A, Montrose Site, Torrance, California, Volume III, September 1988 - November 1988, On-Site Soil Sampling. December 2, 1988.

______, 1999. Dense Non-Aqueous Phase Liquid Feasibility Study, Montrose Site, Torrance, California. September 28, 1999.

______, 2004. Results of DNAPL Reconnaissance Investigation, Montrose Site, Torrance, California, Revision 1.0. October 22, 2004.

______, 2007. DNAPL Extraction Test Summary Report, Montrose Site, Torrance, California, REV 1.0. September 18, 2007.

______, 2008a. Email to J. Dhont, EPA, re DNAPL Thickness Map, dated January 22, 2008.

______, 2008b. Technical Memorandum to J. Dhont, EPA, Re: Results of Field Investigation into the Possible Presence of DNAPL in the Bellflower Sand, Montrose Site, Torrance, California, dated June 24, 2008.

Kavanaugh, M.C. and P.S.C. Rao, Co-Chairs, 2003. "The DNAPL Remediation Challenge: Is There a Case for Source Depletion?", EPA/600/R-03/143, December 2003

Kingston, J.L.T., 2008. A Critical Evaluation of In-Situ Thermal Technologies. A Dissertation Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy, Arizona State University, May 2008.

Newell, C.J. and D.T. Adamson, 2005. "Planning-Level source Decay Models to Evaluate Impact of Source Depletion on Remediation Time Frame", Remediation Autumn 2005.

U.S. Environmental Protection Agency, 1998. Final Remedial Investigation Report for the Montrose Superfund Site, Los Angeles, California. May 18, 1998.

Table A-1. Input Parameter Values

Parameter	*Base Value*	Sensitivity Analysis *Minimum Value*	*Maximum Value*
Empirical Parameter, Γ	1	0.6	1.2
UBA horizontal hydraulic conductivity (ft/day), K_h	15	10	20
Width of DNAPL-impacted zone (ft)	400	--	--
UBA thickness (ft)	40	--	--
Footprint of Entire DNAPL-Impacted Area (ft^2)	162,000	--	--
UBA horizontal gradient (ft/ft), i	0.0025	0.002	0.003
MCB concentration in DNAPL zone (ug/l), C_0	410,000	--	--
Aquitard thickness (ft)	11	--	--
Aquitard hydraulic conductivity (ft/day), K_v	0.0049	0.0039	0.0059
Aquitard head differential (ft)	0.3	--	--
Aquitard vertical gradient (ft/ft), i	0.027	--	--
Concentration goal (ug/l), $C_s(t)$	70	--	--
DNAPL Thickness Parameters (varied concurrently):			
Cross-sectional area (ft^2)	1,314	986	1,643
Starting MCB Mass (lbs), Entire Area, M_0	398,000	298,500	497,500

Note: See spreadsheet provided in Attachment B for details on use of these parameters in the calculation of dissolution timeframes.

Acronyms & Abbreviations:
-- = parameter not evaluated as part of sensitivity analysis, as described in Attachment A
DNAPL = Dense Non-Aqueous Phase Liquid
ft = foot
ft/day = feet per day
ft/ft = feet per foot
ft^2 = square feet
lbs = pounds
MCB = Chlorobenzene
UBA = Upper Bellflower aquitard
ug/l = micrograms per liter

TABLE A-2
BASE CASE ESTIMATE OF MASS IN THE UPPER BELLFLOWER AQUITARD
ENTIRE DNAPL-IMPACTED AREA

	Saturated UBA					Contour Area			
Boring ID	Peak MCB Concentration (mg/kg)	Peak Total DDT Concentration (mg/kg)	Peak DNAPL Concentration (mg/kg)	DNAPL Thickness (feet)	Definite Thickness x Concentration (ft x mg/kg / 1E6)	>50,000 mg/kg	>10,000 mg/kg	>1,000 mg/kg	<1,000 mg/kg
DP- 1	480	170	650	0.50	0.0003				0.0003
DP- 2	210	110	320	0.00					
DP- 3	13,000	8,300	21,300	0.50	0.0107		0.0107		
DP- 4	45	<28	45	0.00					
DP- 5	3,400	2,400	5,800	0.30	0.0017			0.0017	
DP- 7	16,000	12,000	28,000	1.00	0.0280		0.0280		
DP- 8	100	<24	100	0.00					
DP- 9	<30	<30	<60	0.00					
DP- 10	<30	<30	<60	0.00					
DP- 11	<28	<28	<56	0.00					
DP- 12	550	550	1,100	1.25					
PSB- 1	2,400	3,120	5,520	2.50	0.0138			0.0138	
PSB- 2	7,100	9,800	16,900	0.85	0.0144		0.0144		
PSB- 3	3,000	3,150	6,150	1.75	0.0108			0.0108	
PSB- 4	45,000	37,400	82,400	2.95	0.2431	0.2431			
PSB- 5	14,000	16,100	30,100	2.50	0.0753	0.0753			
PSB- 6	27,000	27,100	54,100	0.35	0.0189	0.0189			
PSB- 7	<33	<33	<66	0.00					
PSB- 8	<30	<30	<60	0.00					
PSB- 9	2,000	1,790	3,790	4.00	0.0152			0.0152	
PSB- 10	44	<33	44	0.00					
PSB- 11	3,200	8,700	11,900	2.00	0.0238		0.0238		
PSB- 12	1,400	1,100	2,500	1.55	0.0039			0.0039	
PSB- 13	<51	<51	<102	0.00					
PSB- 14	8,600	9,900	18,500	1.00	0.0185		0.0185		
PSB- 15	13,000	11,000	24,000	1.75	0.0420		0.0420		
PSB- 16	49	<35	49	0.00					
PSB- 17	9,300	12,200	21,500	1.00	0.0215		0.0215		
PSB- 18	5,700	5,900	11,600	1.75	0.0203		0.0203		
PSB- 19	5,200	5,400	10,600	0.25	0.0027		0.0027		
SSB- 1	<21	<21	<42	0.00					
SSB- 2	23,000	25,800	48,800	2.35	0.1147		0.1147		
SSB- 3	<40	<40	<80	0.00					
SSB- 4	N/A	N/A	N/A	0.00					
SSB- 5	2,200	2,330	4,530	0.95	0.0043			0.0043	
SSB- 6	55,000	35,000	90,000	2.50	0.2250	0.2250			

TABLE A-2
BASE CASE ESTIMATE OF MASS IN THE UPPER BELLFLOWER AQUITARD
ENTIRE DNAPL-IMPACTED AREA

	Saturated UBA					Contour Area			
Boring ID	Peak MCB Concentration (mg/kg)	Peak Total DDT Concentration (mg/kg)	Peak DNAPL Concentration (mg/kg)	DNAPL Thickness (feet)	Definite Thickness x Concentration (ft x mg/kg / 1E6)	>50,000 mg/kg	>10,000 mg/kg	>1,000 mg/kg	<1,000 mg/kg
SSB- 7	<2,000	6,200	6,200	1.50	0.0093			0.0093	
SSB- 8	<40	<40	<80	0.00					
SSB- 9	<45	<45	<90	0.00					
SSB- 10	<40	<40	<80	0.00					
SSB- 11	990	1,400	2,390	0.70	0.0017			0.0017	
SSB- 12	50,000	53,000	103,000	1.00	0.1030	0.1030			
SSB- 13	<40	<40	<80	0.00					
SSB- 14	<40	<40	<80	0.00					
SSB- 15	<34	<34	<68	0.00					
TSB- 1	<50	<50	<100	0.00					
TSB- 2	28,000	20,700	48,700	0.30	0.0146		0.0146		
TSB- 3	14,000	12,900	26,900	1.60	0.0430		0.0430		
TSB- 4	<30	<30	<60	0.00					
TSB- 5	44	<34	44	0.00					
TSB- 6	<36	<36	<72	0.00					
TSB- 7	<34	<34	<68	0.00					
TSB- 8	13,000	8,000	21,000	0.95	0.0200		0.0200		
TSB- 9	47	<35	47	0.00					
TSB- 10	46	<34	46	0.00					
TSB- 11	280	100	380	0.00					
TSB- 12	<40	<40	<80	0.00					
TSB- 13	45	<40	45	0.00					
TSB- 14	40	<35	40	0.00					
TSB- 15	<35	<35	<70	0.00					
TSB- 16	<40	<40	<80	0.00					
C- 13	<30	<30	<60	0.00					
C- 30	8,300	6,600	14,900	2.00	0.0298		0.0298		
C- 42	<35	<35	<70	0.00					
C- 44	4,100	3,860	7,960	1.00	0.0080			0.0080	
C- 59	66	<40	66	0.00					
S- 101/10	36,000	51,000	87,000	1.05	0.0914	0.0914			
S- 201	N/A	N/A	N/A	N/A					
S- 202	N/A	N/A	N/A	N/A					
S- 203	N/A	N/A	N/A	N/A					
S- 204	N/A	N/A	N/A	N/A					
S- 301/30	12,000	3,800	15,800	1.20	0.0190		0.0190		
S- 302A	54	88	142	1.45	0.0002				0.0002

TABLE A-2
BASE CASE ESTIMATE OF MASS IN THE UPPER BELLFLOWER AQUITARD
ENTIRE DNAPL-IMPACTED AREA

	Saturated UBA					Contour Area			
Boring ID	Peak MCB Concentration (mg/kg)	Peak Total DDT Concentration (mg/kg)	Peak DNAPL Concentration (mg/kg)	DNAPL Thickness (feet)	Definite Thickness x Concentration (ft x mg/kg / 1E6)	>50,000 mg/kg	>10,000 mg/kg	>1,000 mg/kg	<1,000 mg/kg
S- 302E/3	N/A	N/A	N/A	1.45					
S- 303/30	1	8	9	0.00					
S- 304/30	4,900	69,000	73,900	1.00	0.0739	0.0739			
S- 305/30	81,000	24,000	105,000	2.20	0.2310	0.2310			
MW- 2	7,400	4,980	12,380	N/A					
UBT- 1	N/A	N/A	N/A	14.15		0.231*			
UBT- 2	N/A	N/A	N/A	7.55		0.231*			
UBT- 3	N/A	N/A	N/A	4.50		0.231*			
LW- 1	N/A	N/A	N/A	1.30					

	>50,000 mg/kg	>10,000 mg/kg	>1,000 mg/kg	<1,000 mg/kg	
Average (ft x mg/kg / 1E6) =	0.1595	0.0282	0.0076	0.0003	Subtotal
Area (sq ft) =	30,492	58,141	50,447	23,045	162,125
Wet bulk density (g/cc) =	1.85	1.85	1.85	1.85	
DNAPL Mass (lbs) =	561,686	189,267	44,391	706	796,051
DNAPL density (g/cc) =	1.25	1.25	1.25	1.25	
DNAPL Volume (gals) =	53,844	18,143	4,255	68	76,310

Notes:

* For purposes of DNAPL mass estimation, recovery wells UBT-1 through UBT-3 were assigned a (thickness x concentration) product of 0.2310 ft x mg/kg/1E6, consistent with the value measured at S-305/305A.

FOOTNOTES

UBA = Upper Bellflower aquitard
MCB = Chlorobenzene
DDT = Dichlorodiphenyltrichloroethane
DNAPL = Dense non-aqueous phase liquid
(>) = Greater than
(<) = Less than
mg/kg = Milligrams per kilogram
N/A = Not analyzed
sq ft = Square feet
g/cc = Grams per cubic centimeter
lbs = Pounds
gals = Gallons

TABLE A-3
BASE CASE ESTIMATE OF MASS IN THE UPPER BELLFLOWER AQUITARD
FOCUSED TREATMENT AREA

	Saturated UBA					Definite DNAPL Thickness x Concentration (ftxmg/kg/1E6)	
Boring ID	Peak MCB Concentration (mg/kg)	Peak Total DDT Concentration (mg/kg)	Peak DNAPL Concentration (mg/kg)	DNAPL Thickness (feet)	Definite Thickness x Concentration (ft x mg / kg / 1E6)	Focused Treatment Area	SSB-12 Area
PSB-4	45,000	37,400	82,400	2.95	0.24308	0.24308	
PSB-5	14,000	16,100	30,100	2.50	0.07525	0.07525	
PSB-6	27,000	27,100	54,100	0.35	0.018935	0.018935	
SSB-6	55,000	35,000	90,000	2.50	0.225	0.225	
SSB-12	50,000	53,000	103,000	1.00	0.103		0.103
S-101/101A	36,000	51,000	87,000	1.05	0.09135	0.09135	
S-304/304A	4,900	69,000	73,900	1.00	0.0739	0.0739	
S-305/305A	81,000	24,000	105,000	2.20	0.231	0.231	
UBT-1	N/A	N/A	N/A	14.15	N/A	0.231*	
UBT-2	N/A	N/A	N/A	7.55	N/A	0.231*	
UBT-3	N/A	N/A	N/A	4.50	N/A	0.231*	

	Focused Treatment Area	SSB-12 Area	Total
Average (ft x mg/kg / 1E6) =	**0.1652**	**0.103**	
Area (sq ft) =	**22,900**	**3,100**	**26,000**
Wet bulk density (g/cc) =	**1.85**	**1.85**	
DNAPL Mass (lbs) =	**436,779**	**36,876**	**473,655**
DNAPL density (g/cc) =	**1.25**	**1.25**	
DNAPL Volume (gals) =	**41,870**	**3,535**	**45,405**

Notes:

* For purposes of DNAPL mass estimation, recovery wells UBT-1 through UBT-3 were assigned a (thickness x concentration) product of 0.231 ft x mg/kg/1E6, consistent with the value measured at S-305/305A.

1. Estimated residual DNAPL concentration is 53,000 mg/kg.

FOOTNOTES

UBA = Upper Bellflower aquitard
MCB = Chlorobenzene
DDT = Dichlorodiphenyltrichloroethane
DNAPL = Dense non-aqueous phase liquid
mg/kg = Milligrams per kilogram
N/A = Not analyzed
sq ft = Square feet
g/cc = Grams per cubic centimeter
lbs = Pounds
gals = Gallons

TABLE A-4
BASE CASE ESTIMATE OF MOBILE MASS IN THE UPPER BELLFLOWER AQUITARD
FOCUSED TREATMENT AREA

	Saturated UBA					Definite DNAPL Thickness x Concentration (ftxmg/kg/1E6)	
Boring ID	Peak MCB Concentration (mg/kg)	Peak Total DDT Concentration (mg/kg)	Peak DNAPL Concentration (mg/kg)	DNAPL Thickness (feet)	Magnitude of Concentration Above Residual Concentration[1] (mg/kg)	Focused Treatment Area	SSB-12 Area
PSB-4	45,000	37,400	82,400	2.95	29,400	0.08673	
PSB-6	27,000	27,100	54,100	0.35	1,100	0.000385	
SSB-6	55,000	35,000	90,000	2.50	37,000	0.0925	
SSB-12	50,000	53,000	103,000	1.00	50,000		0.05
S-101/101A	36,000	51,000	87,000	1.05	34,000	0.0357	
S-304/304A	4,900	69,000	73,900	1.00	20,900	0.0209	
S-305/305A	81,000	24,000	105,000	2.20	52,000	0.1144	
UBT-1	N/A	N/A	N/A	14.15	N/A	0.1144*	
UBT-2	N/A	N/A	N/A	7.55	N/A	0.1144*	
UBT-3	N/A	N/A	N/A	4.50	N/A	0.1144*	

Average (ft x mg/kg / 1E6) =	0.0771	0.05	Total
Area (sq ft) =	22,900	3,100	26,000
Wet bulk density (g/cc) =	1.85	1.85	
Mobile DNAPL Mass (lbs) =	203,883	17,901	221,784
DNAPL density (g/cc) =	1.25	1.25	
Mobile DNAPL Volume (gals) =	19,544	1,716	21,260

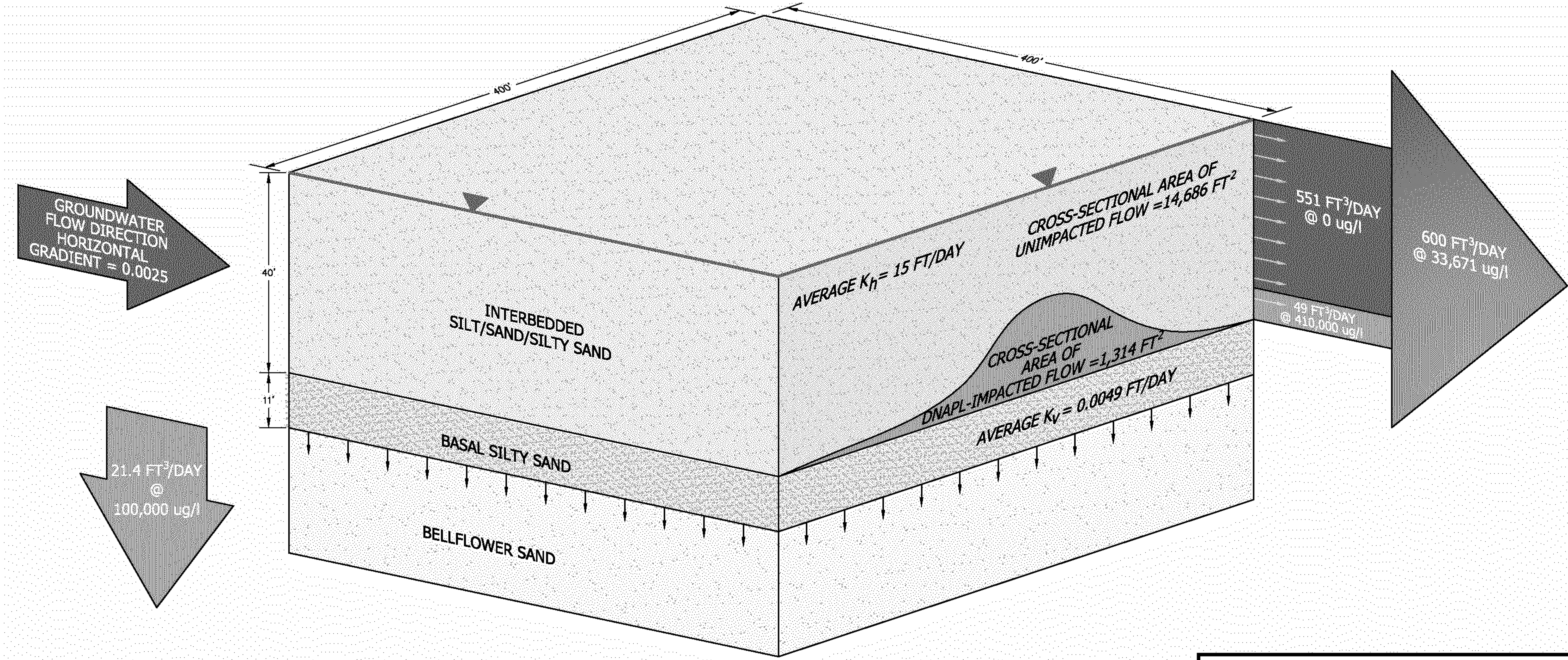
Notes:

* For purposes of mobile DNAPL mass estimation, recovery wells UBT-1 through UBT-3 were assigned a (thickness x concentration) product of 0.1144 ft x mg/kg/1E6, consistent with the value measured at S-305/305A.

1. Estimated residual DNAPL concentration is 53,000 mg/kg.

FOOTNOTES

UBA = Upper Bellflower aquitard
MCB = Chlorobenzene
DDT = Dichlorodiphenyltrichloroethane
DNAPL = Dense non-aqueous phase liquid
mg/kg = Milligrams per kilogram
N/A = Not analyzed
sq ft = Square feet
g/cc = Grams per cubic centimeter
lbs = Pounds
gals = Gallons



NOT TO SCALE

MONTROSE CHEMICAL CORPORATION OF CALIFORNIA
TORRANCE, CALIFORNIA

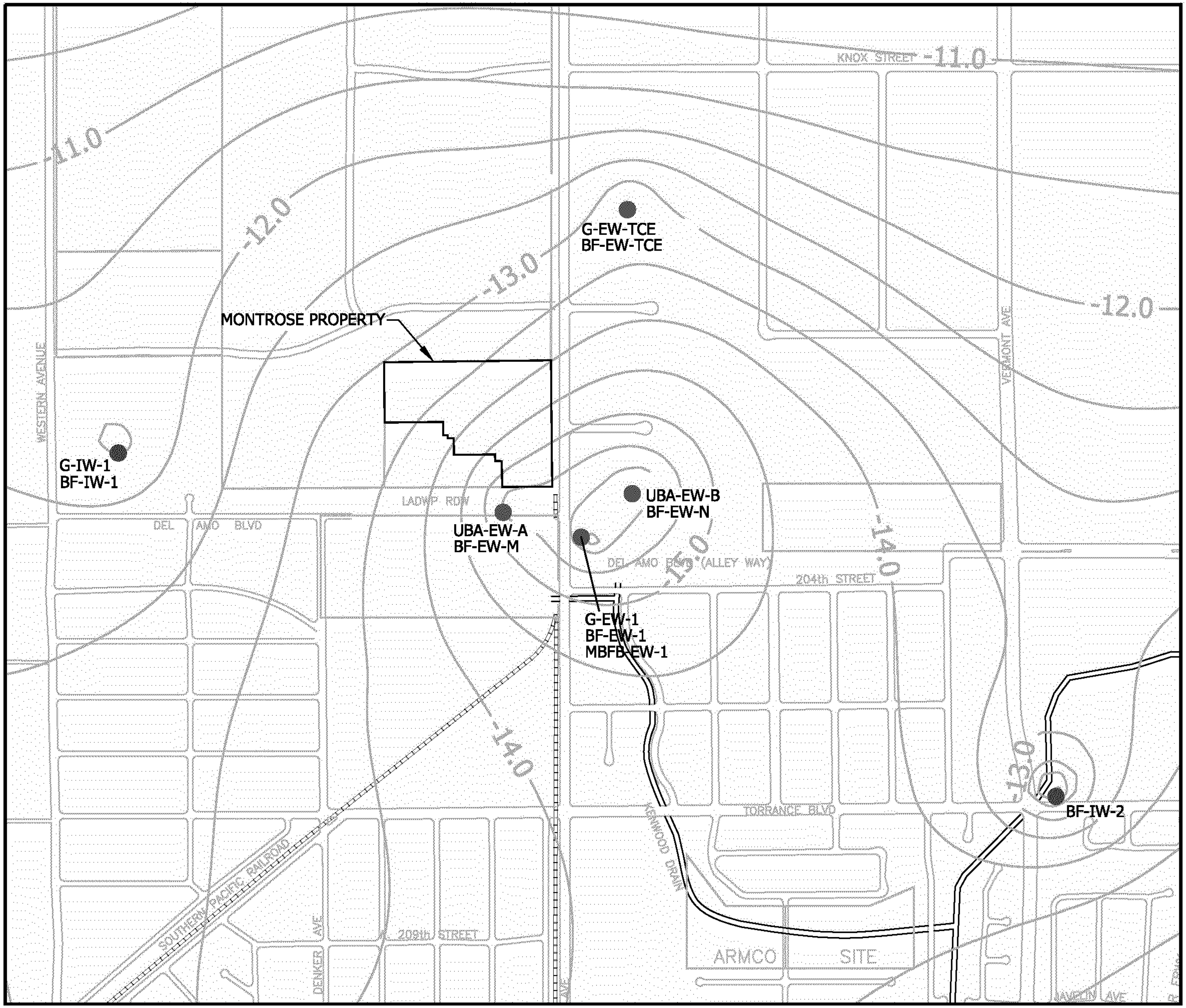
CONCEPTUAL MODEL IN THE UPPER BELLFLOWER AQUITARD

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

02/09

FIGURE A-1

PREP BY RAN	REV BY DMO	RPT NO. 857.04C	310-0913	A



EXPLANATION

UBA-EW-B ● EXTRACTION WELL

BF-IW-2 ● INJECTION WELL

WATER LEVEL ELEVATION CONTOUR LINES, IN FEET ABOVE MEAN SEA LEVEL. BASED ON SIMULATION OF HYDRAULIC CONTAINMENT SCENARIO USING REMEDIAL DESIGN MODEL.

WELL IDENTIFIERS

UBA - INDICATES WELL SCREENED IN THE UPPER BELLFLOWER AQUITARD

BF - INDICATES WELL SCREENED IN THE BELLFLOWER SAND

G - INDICATES WELL SCREENED IN THE GAGE AQUIFER

EW - EXTRACTION WELL

IW - INJECTION WELL

N

0 600 1,200

FEET

MONTROSE CHEMICAL CORPORATION OF CALIFORNIA
TORRANCE, CALIFORNIA

SIMULATED WATER LEVEL ELEVATIONS UPPER BELLFLOWER AQUITARD HYDRAULIC CONTAINMENT PUMPING SCENARIO

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

5/08

FIGURE A-2

PREP BY RDC REV BY MAP RPT NO. 857.04F 410-6594 C

ATTACHMENT B

DISSOLUTION TIMEFRAME CALCULATIONS

(Provided on CD only)

DESCRIPTION OF SPREADSHEETS
FOR CALCULATION OF DISSOLUTION TIMEFRAMES

Input-Output Sheet

This sheet is used to enter the inputs for various parameters used for calculation throughout the workbook. **This is the only sheet where data should be entered.** Input values are entered in cells B4 through B16 for the appropriate parameters and units listed in column A.

The results of the model are listed in the table labeled **RESULTS** (cells A21-E33). The mass reduction percentages (cells B23-B33) and gamma values (cells C22-D22) can be modified on this sheet and will carry through to the calculations on other sheets. The "Time to reach ISGS after remedy" presents the time in years to reach the goal concentration for each scenario listed in the column; cells C23-E33 reference the results that are calculated on the appropriate sheet for each treatment scenario; the sheets are titled "Timeframe-Entire Area" and "Timeframe-Focused Area" should not be manually updated.

Timeframe-Entire Area Sheet

This sheet calculates the timeframes for scenarios involving treatment in the entire DNAPL-impacted area. No inputs are required.

The **INPUT CALCUALTIONS** calculate M_t and C_t, which are inputs to the main calculations of dissolution timeframes (cells C8-F10).

The results of the model are output in the table labeled **RESULTS** (cells C15-E17).

The unit conversions/interim calculations below the results tables convert the calculated groundwater flowrates, mass loadings, and concentrations calculated in the "Flow Rate & Mass" to the forms required by the calculation, as specified in Falta et al. (2005). Additionally, the values are converted to the metric system in order to simplify the calculations. Standard unit conversions are listed under **CONVERSIONS.**

Initial mass, M_0, is the estimate chlorobenzene mass in the UBA, converted to kilograms (kg).

The term V_d*A is the Darcy velocity times the cross-sectional area, and is equivalent to the groundwater flow rate through the DNAPL source zone. In this evaluation, the horizontal and vertical groundwater flow rates are summed together to represent the total groundwater flow rate through the DNAPL source zone. This total groundwater flow rate is converted to liters per year using the standard conversion listed under **CONVERSIONS.**

Initial concentration, C_0, is the calculated average concentration in the UBA, converted to killogram per liter (kg/l).

The goal concentration is the ISGS, converted to kg/l.

Timeframe-Focused Area Sheet

This sheet calculates the timeframes for scenarios involving treatment in the focused area. No inputs are required.

This sheet is set up identically to the above sheet that calculates the timeframes for the scenarios involving treatment of the entire DNAPL-impacted area.

The **INPUT CALCULATIONS** are presented in cells C8-F13.

The **RESULTS** are presented in cells C18-E23.

DESCRIPTION OF SPREADSHEETS
FOR CALCULATION OF DISSOLUTION TIMEFRAMES

Flow Rate & Mass Sheet

This sheet calculates the groundwater flow rates, mass loadings, and average concentrations for various portions of the simplified UBA model. No inputs are required for this sheet, and **no modifications should be made to this sheet**. All inputs are from the sheet labeled "Input-Output".

This sheet is divided into 4 sections –
1. Chlorobenzene Mass
2. Horizontal Transport Only
3. Vertical Transport Only
4. Combined Horizontal and Vertical Transport

The mass of chlorobenzene in the UBA is calculated separately using DNAPL thickness estimates and soil analytical data, as described in the technical memorandum. The horizontal calculations relate to the components of groundwater and chlorobenzene mass transport in the horizontal dimension through the permeable portion of the UBA only. The vertical transport calculations relate to the component of groundwater flow rate from the UBA, downward through the base of the UBA into the BFS. The combined horizontal and vertical flow rates sums the magnitude of the two flow rates (horizontal and vertical).

The following points should also be noted:

1. For the horizontal transport, it was assumed that the UBA is split into two zones – a "Non-DNAPL zone" and a "DNAPL zone" for the purposes of calculating groundwater and chlorobenzene mass transport. The cross-sectional area of flow for the DNAPL zone is calculated separately, based on DNAPL thickness estimates, as described in the technical memorandum. The cross-sectional area of flow for the Non-DNAPL zone is calculated using the input width times the thickness of the Non-DNAPL zone, minus the area of the DNAPL zone. These values are provided in cells C9 and C10. The horizontal components of groundwater flow are calculated separately for each of these zones using Darcy's law, $Q=K_hiA$, where Q is flow rate, K_h is the horizontal hydraulic conductivity (input), i is the horizontal gradient (input), and A is the cross-sectional area for each zone as described above. The groundwater flow rate is calculated in cells C12 and C13 for each zone. The horizontal component of chlorobenzene mass loading from the DNAPL-impacted zone is calculated by first converting the concentration of chlorobenzene in the DNAPL zone from micrograms per liter to pounds per cubic feet, using standard conversion factors, in cell C15. This concentration is then multiplied by the groundwater flow rate in the DNAPL zone to yield the mass loading of chlorobenzene in the DNAPL zone in pounds per year in cell C16. After groundwater leaves the DNAPL zone, it was assumed that the dissolved-phase chlorobenzene mixes ideally throughout the UBA to create an average concentration throughout the entire thickness of the UBA. Therefore, the total groundwater flow rate for both the non-DNAPL zone and the DNAPL zone is summed in cell C18. The mass loading from the DNAPL zone is divided by the total groundwater flow rate to calculate the average concentration for this scenario in cell C19; this calculation requires the conversion of cubic feet per day to liters per year and pounds to micrograms to yield a concentration in micrograms per liter.

2. For the calculation of the vertical component of mass loading from the UBA DNAPL zone to the BFS, the idealized horizontal extent of DNAPL impact was assumed to be the aerial extent of the entire DNAPL-impacted area, as shown in cell C23. The groundwater flow rate through the base of the UBA into the BFS is then calculated in cell C25 using Darcy's law as described above; the input values for the vertical hydraulic conductivity and gradient differ from the horizontal values within the UBA. The average concentration of chlorobenzene in groundwater flowing vertically through the base of the UBA into the BFS is defined in cell C27 and is assumed to be equal to the maximum concentration of chlorobenzene observed in the BFS near the area of DNAPL impact in the UBA. In cell C28, the concentration is converted to pounds per cubic feet. The mass loading is then calculated in cell C29 by multiplying the converted concentration by the vertical groundwater flow rate and converting to pounds per year.

DESCRIPTION OF SPREADSHEETS
FOR CALCULATION OF DISSOLUTION TIMEFRAMES

3. The magnitude of the groundwater flow rate and the mass loading are summed in cells C33 and C34 for use in the calculations of dissolution timeframes on the "Timeframe" sheets.

4. Beginning on Row 38, the calculation inputs are repeated. These are the same values as the input parameters on the sheet titled "Input-Output" and refer to the values input on that sheet. The parameters should NOT be modified on the sheet titled "Flow Rate & Mass". These values were repeated on this sheet to make referencing values for the calculations on this sheet simpler.

Constants for performing unit conversions are provided beginning on Row 45.

INPUT PARAMETERS, SUMMARY TABLE

Parameter (units)	Calculation Inputs
UBA K_h (ft/day)	15
Width of DNAPL-impacted zone (ft)	400
UBA thickness (ft)	40
Footprint of entire DNAPL-impacted zone (ft^2)	162,000
UBA horizontal gradient (ft/ft)	0.0025
MCB concentration DNAPL zone (ug/l)	410,000
Aquitard layer thickness (ft)	11
Aquitard K_v (ft/day)	0.0049
Aquitard head differential (ft)	0.3
Aquitard vertical gradient (ft/ft) *[calculated]*	0.027
Concentration goal (ug/l)	70
DNAPL Thickness Parameters (varied concurrently):	
Cross-Sectional Area, DNAPL-impacted zone (ft^2)	1,314
Starting MCB Mass (lbs), Entire Area	398,100
Total MCB Mass in Focused Treatment Area	60%
Mobile MCB Mass in Focused Treatment Area	28%

DNAPL = Dense non-aqueous phase liquid
ft = foot
ft^2 = square feet
ft/day = feet per day
ft/ft = feet per foot
ISGS = In-situ groundwater standard
lbs = pounds
K_h = horizontal hydraulic conductivity
K_v = vertical hydraulic conductivity
MCB = Chlorobenzene
UBA = upper Bellflower aquitard
ug/l = micrograms per liter

RESULTS

DNAPL Remedy	Chlorobenzene Mass Reduction, Entire Area	Time to reach ISGS after remedy (years) $\Gamma = 0.6$	$\Gamma = 1.0$	$\Gamma = 1.2$
Treatment of Entire DNAPL-Impacted Area				
Containment Only	0%	1,920	4,880	7,150
Thermal	60%	1,320	4,160	6,370
	80%	1,000	3,620	5,670
	90%	750	3,080	4,870
Focused Treatment				
Hydraulic Displacement	17%	1,790	4,740	7,010
	22%	1,740	4,680	6,950
	25%	1,710	4,650	6,920
Thermal	36%	1,600	4,530	6,790
	48%	1,470	4,370	6,610
	54%	1,400	4,270	6,500

Note: for the case when gamma is shown as equal to one, the equation uses a value of 0.9999.

These columns pull values from the 'Timeframe' sheets

CALCULATION OF TIME TO REACH ISGS

Treatment Area: Entire DNAPL-Impacted Area

INPUT CALCULATIONS

DNAPL Remedy	MCB Mass Reduction	M_t, MCB Mass After Remedy (kg)	Ct, MCB Concentration After Remedy (kg/L)			
			$\Gamma = 0.6$	$\Gamma = 1.0$	$\Gamma = 1.2$	*[input] (Empirical constant, >0)*
Containment-Only	0%	180,575	3.60E-05	3.60E-05	3.60E-05	Equations (5) and (6) from Attachment A
Thermal	60%	72,230	2.08E-05	1.44E-05	1.20E-05	Equations (5) and (6) from Attachment A
	80%	36,115	1.37E-05	7.19E-06	5.21E-06	Equations (5) and (6) from Attachment A
	90%	18,058	9.03E-06	3.60E-06	2.27E-06	Equations (5) and (6) from Attachment A

RESULTS

DNAPL Remedy	MCB Mass Reduction	Time to reach ISGS after remedy (years)			
		$\Gamma = 0.6$	$\Gamma = 1.0$	$\Gamma = 1.2$	
Containment-Only	0%	1,924	4,879	7,154	Equation (7) from Attachment A
Thermal	60%	1,324	4,163	6,368	Equation (7) from Attachment A
	80%	996	3,621	5,669	Equation (7) from Attachment A
	90%	748	3,079	4,867	Equation (7) from Attachment A

Unit Conversions/Interim Calculations

M_0 =	180,575	kg	[calc]	*Initial MCB DNAPL Mass from 'Flow Rate & Mass', converted to kg*
V_d*A =	6,422,909	l/yr	[calc]	*Initial Groundwater Flow Rate from 'Flow Rate & Mass', converted to l/yr*
C_0 =	3.60E-05	kg/l		*Initial avgerage MCB conc., combined vertical & horizontal, from 'Flow Rate & Mass'*
Goal Concentration =	7.00E-08	kg/l	[calc]	*ISGS concentration for MCB, converted to kg/l*

Conversions

1 kg =	2.20	lbs
1 ft3 =	28.32	liters
1 kg =	1.00E+09	ug

kg = kilograms
l/yr = liters per year
lbs = pounds
ug = micrograms
ft^3 = cubic feet

MCB = Chlorobenzene
kg/l = Kilograms per liter
M_0 = initial mass
C_0 = initial concentration
ISGS = In-situ groundwater standard

Vd = Darcy velocity
A = cross-sectional area
> = greater than

CALCULATION OF TIME TO REACH ISGS

Treatment Area: **Focused Treatment Area**

INPUT CALCULATIONS

DNAPL Remedy	MCB Mass Reduction	M_t, MCB Mass After Remedy (kg)	Ct, MCB Concentration After Remedy (kg/L) $\Gamma = 0.6$	$\Gamma = 1.0$	$\Gamma = 1.2$	*[input] (Empirical constant, >0)*
Hydraulic Displacement	17%	150,239	3.22E-05	2.99E-05	2.88E-05	Equations (5) and (6) from Attachment A
	22%	140,126	3.09E-05	2.79E-05	2.65E-05	Equations (5) and (6) from Attachment A
	25%	135,070	3.02E-05	2.69E-05	2.54E-05	Equations (5) and (6) from Attachment A
Thermal	36%	115,568	2.75E-05	2.30E-05	2.10E-05	Equations (5) and (6) from Attachment A
	48%	93,899	2.43E-05	1.87E-05	1.64E-05	Equations (5) and (6) from Attachment A
	54%	83,065	2.26E-05	1.65E-05	1.42E-05	Equations (5) and (6) from Attachment A

RESULTS

DNAPL Remedy	MCB Mass Reduction	Time to reach ISGS after remedy (years) $\Gamma = 0.6$	$\Gamma = 1.0$	$\Gamma = 1.2$	
Hydraulic Displacement	17%	1,786	4,735	7,007	Equation (7) from Attachment A
	22%	1,736	4,681	6,950	Equation (7) from Attachment A
	25%	1,710	4,652	6,920	Equation (7) from Attachment A
Thermal	36%	1,605	4,530	6,789	Equation (7) from Attachment A
	48%	1,474	4,368	6,608	Equation (7) from Attachment A
	54%	1,402	4,272	6,497	Equation (7) from Attachment A

Unit Conversions/Interim Calculations

M_0 =	180,575	kg	[calc]	*Initial MCB DNAPL Mass from 'Flow Rate & Mass', converted to kg*
V_d*A =	6,422,909	l/yr	[calc]	*Initial Groundwater Flow Rate from 'Flow Rate & Mass', converted to l/yr*
C_0 =	3.60E-05	kg/l		*Initial avgerage MCB conc., combined vertical & horizontal, from 'Flow Rate & Mass'*
Goal Concentration =	7.00E-08	kg/l	[calc]	*ISGS concentration for MCB, converted to kg/l*

Conversions

1 kg =	2.20	lbs
1 ft3 =	28.32	liters
1 kg =	1.00E+09	ug

kg = kilograms
l/yr = liters per year
lbs = pounds
ug = micrograms
ft^3 = cubic feet
MCB = Chlorobenzene
kg/l = Kilograms per liter
M_0 = initial mass
C_0 = initial concentration
ISGS = In-situ groundwater standard
Vd = Darcy velocity
A = cross-sectional area
> = greater than
ERH = Electrical resistance heating

CALCULATION OF GROUNDWATER FLOWRATE AND MASS LOADING VALUES

1. Chlorobenzene mass

Total Chlorobenzene mass	Mass of MCB (lbs)	398,100	*(assume 50% of total DNAPL mass)*

2. HORIZONTAL TRANSPORT ONLY

Calculate cross-sectional areas	Non-DNAPL zone (ft^2)	14,686	*(total UBA thickness*width of DNAPL impacted area) - area of DNAPL zone*
	DNAPL zone (ft^2)	1314	*(cumulative cross-sectional area impacted with DNAPL, per Surfer)*
Calculate GW flow rate	Non-DNAPL zone (ft^3/day)	550.73	*Q=KAi*
	DNAPL zone (ft^3/day)	49.28	*Q=KAi*
Calculate mass loading	Convert MCB conc to lbs/ft^3	0.026	*[=ug/l*l/ft^3 *lbs/kg*kg/ug]*
	Mass loading of MCB (lbs/yr)	459	*(MCB concentration *GW flow rate through DNAPL zone), converted to lbs/yı*
Calculate aggregate GW concentration	Total GW flow rate (ft^3/day)	600	*(DNAPL zone + non-DNAPL zone GW flow rate)*
	Concentration (ug/l)	33,671	*(mass floading/GW flow rate), converted to ug/l*

3. VERTICAL TRANSPORT ONLY

Cross-sectional area	DNAPL-impacted zone (ft^2)	162,000	*area within estimated extent of confirmed DNAPL*
Calculate GW flow rate through aquitard	DNAPL-impacted zone (ft^3/day)	21.43	*Q=KAi*
Calculate mass loading	MCB concentration (ug/l)	100,000	*(MCB concentration going through the aquitard)*
	Convert MCB conc to lbs/ft^3	0.006	*[=ug/l*l/ft^3 *lbs/kg*kg/ug]*
	Mass loading of MCB (lbs/yr)	48.7	*(MCB concentration*GW flow rate), converted to ug/l*

4. HORIZONTAL + VERTICAL TRANSPORT

TOTAL GW FLOW RATE (ft^3/day)	621	
TOTAL MCB MASS LOADING (lbs/yr)	508.2	
AVERAGE INITIAL MCB CONCENTRATION (kg/l)	3.60E-05	*(average, initial MCB concentration out of both the vertical & horizontal planes, converted to kg/l)*

CALCULATION OF GROUNDWATER FLOWRATE AND MASS LOADING VALUES

Calculation Inputs (Values from 'Input-Output' sheet. Do not change values here.)

UBA K_h (ft/day)	15	UBA horizontal gradient (ft/ft)	0.0025
Cross-Sectional Area, DNAPL-impacted zone (ft^2)	1314	MCB concentration in DNAPL zone (ug/l)	410,000
Width of DNAPL-impacted zone (ft)	400	Aquitard K_v (ft/day)	0.0049
UBA thickness (ft)	40	Aquitard vertical gradient, i (ft/ft) *[calculated]*	0.027
Footprint of DNAPL-impacted zone (ft^2)	162,000	Starting Chlorobenzene Mass (lbs)	398,100

Constants & Conversions

1 ft^3 =	28.32	Liters
1 kg =	2.20	lbs
1 kg =	1.00E+09	ug

Abbreviations & Acronyms:

A = cross-sectional area
ft = foot
ft/day = feet per day
ft/ft = feet per foot
ft^2 = square feet
ft^3 = cubic feet
ft^3/day = cubic feet per day
i = gradient
kg = kilograms
K = hydraulic conductivity
K_h = horizontal hydraulic conductivity
K_v = vertical hydraulic conductivity
lbs = pounds
lbs/ft^3 = pounds per cubic foot
lbs/yr = pounds per year
MCB = Chlorobenzene
UBA = upper Bellflower aquitard
ug/l = micrograms per liter
Q = flow
l/ft^3 = liters per cubic feet
lbs/kg = pounds per kilogram
kg/ug = kilograms per micrograms
ug/l = micrograms per liter
ug = micrograms
kg/l = kilograms per liter

Appendix H

Carbon Footprint Analysis

H-1 – Carbon Dioxide Emissions Summary
H-2 – Carbon Dioxide Emissions from On-Site Natural Gas Usage
H-3 – Carbon Dioxide Emissions from On-Site Electricity Usage
Electricity Generation from Natural Gas
H-4 – Carbon Dioxide Emissions from On-Site Electricity Usage
Electricity Generation from Coal

Table H-1
Carbon Footprint Analysis - Carbon Dioxide Emissions Summary
Montrose Superfund Site

RA	Remedial Technology	On-Site Electricity and Natural Gas Usage: Total Mass of CO_2 Released (lbs)	On-Site Electricity and Natural Gas Usage: Total Mass of CO_2 Released (Kg)	Total Carbon Offsets & Equivalents: Trees Required[1] to Offset CO_2	Total Carbon Offsets & Equivalents: Acres[1] Required to Support Trees
1	**No Action, Hydraulic Containment**				
	No Action, Hydraulic Containment	0[3]	0	0	0
2	**ICs, Hydraulic Containment**				
	ICs, Hydraulic Containment	0	0	0	0
3	**SVE, ICs, Hydraulic Containment**				
	Stand Alone SVE	2,193,343	994,884	14,199	24
	ICs, Hydraulic Containment	NA	NA	NA	NA
	Total	**2,193,343**	**994,884**	**14,199**	**24**
4	**Hydraulic Displacement without Groundwater Treatment, SVE, ICs, Hydraulic Containment**				
	Hydraulic Displacement without Groundwater Treatment	2,018,707	915,670	13,068	22
	Stand Alone SVE	2,193,343	994,884	14,199	24
	ICs, Hydraulic Containment	NA	NA	NA	NA
	Total	**4,212,050**	**1,910,554**	**27,267**	**45**
5a	**Steam Injection over Focused Treatment Area, SVE, ICs, Hydraulic Containment**				
	Focused 2 UBA and 2.5 HF PVs - Lower Realistic	*36,662,027*	*16,629,616*	*237,330*	*396*
	Focused 3 UBA and 3.5 HF PVs - Upper Realistic	*49,484,197*	*22,445,654*	*320,334*	*534*
	Average Steam Injection over Focused Treatment Area	43,073,112	19,537,635	278,832	465
	SVE if Coupled with Focused Treatment Area Thermal	2,865,178	1,299,623	18,548	31
	ICs, Hydraulic Containment	NA	NA	NA	NA
	Total	**45,938,291**	**20,837,258**	**297,380**	**496**
5b	**Steam Injection over Entire DNAPL-Impacted Area, SVE, ICs, Hydraulic Containment**				
	Full-Scale 2 UBA and 2.5 HF PVs - Lower Realistic	*144,619,332*	*65,598,226*	*936,189*	*1,560*
	Full-Scale 3 UBA and 3.5 HF PVs - Upper Realistic	*201,438,741*	*91,371,076*	*1,304,007*	*2,173*
	Average Full-Scale Steam Injection	173,029,037	78,484,651	1,120,098	1,867
	SVE if Coupled with Full-Scale Thermal	2,459,380	1,115,556	15,921	27
	ICs, Hydraulic Containment	NA	NA	NA	NA
	Total	**175,488,417**	**79,600,207**	**1,136,019**	**1,893**
6a	**ERH over Focused Treatment Area, SVE, ICs, Hydraulic Containment**				
	ERH over Focused Treatment Area without Hot Floor	10,812,818	*4,904,612*	69,996	117
	SVE if Coupled with Focused Treatment Area Thermal	2,865,178	1,299,623	18,548	31
	ICs, Hydraulic Containment	NA	NA	NA	NA
	Total	**13,677,997**	**6,204,235**	**88,544**	**148**
6b	**ERH over Entire DNAPL-Impacted Area, SVE, ICs, Hydraulic Containment**				
	Full-Scale ERH without Hot Floor	55,157,694	25,019,109	357,062	595
	SVE if Coupled with Full-Scale Thermal	2,459,380	1,115,556	15,921	27
	ICs, Hydraulic Containment	NA	NA	NA	NA
	Total	**57,617,074**	**26,134,665**	**372,982**	**622**

Notes:

[1] Average carbon sequestering capability of trees = 70.1 Kg CO_2 per tree; 600 trees per acre;
Source: NewFields, *Remediation Carbon Footprint Analysis for Central Chemical Respondents Group, May 2008*

[2] O&M duration includes pilot testing pre-heating where applicable

[3] Hydraulic Containment is a component of all DNAPL Remedial Alternatives

CO_2 = Carbon Dioxide

lbs = Pounds

Kg = Kilograms

RA = Remedial Alternative

Table H-2
Carbon Footprint Analysis - Carbon Dioxide Emissions from On-Site Natural Gas Usage
Montrose Superfund Site

Remedial Technology	Natural Gas Usage	Natural Gas[1] Energy Content	Volume of Natural Gas Consumed	Density[2] of Natural Gas	Mass Natural Gas Consumed	Carbon[3] Content of Natural Gas	Mass CO_2 Released per pound of Carbon	Mass CO_2 Released[4]
	(Therms)	(BTUs/CF)	(CF)	(lbs/CF)	(lbs)	(%)	(lbs)	(lbs)
Steam Injection								
Full-Scale 2 UBA and 2.5 HF PVs - Lower Realistic	9,193,824	1,027	894,997,948	0.05	44,749,897	76	3.667	124,714,384
Full-Scale 3 UBA and 3.5 HF PVs - Upper Realistic	13,382,496	1,027	1,302,755,683	0.05	65,137,784	76	3.667	181,533,793
Average Full-Scale	11,288,160	1,027	1,098,876,815	0.05	54,943,841	76	3.667	153,124,089
Focused 2 UBA and 2.5 HF PVs - Lower Realistic	2,349,886	1,027	228,756,081	0.05	11,437,804	76	3.667	31,876,245
Focused 3 UBA and 3.5 HF PVs - Upper Realistic	3,295,124	1,027	320,772,860	0.05	16,038,643	76	3.667	44,698,415
Average Focused Treatment Area	2,822,505	1,027	274,764,471	0.05	13,738,224	76	3.667	38,287,330
ERH								
Full-Scale	286,411	1,027	27,881,462	0.05	1,394,073	76	3.667	3,885,170
Focused Treatment Area	53,702	1,027	5,227,768	0.05	261,388	76	3.667	728,469
SVE								
Stand Alone SVE	0	1,027	0	0.05	0	76	3.667	0
SVE if Coupled with Full-Scale Thermal	114,564	1,027	11,152,546	0.05	557,627	76	3.667	1,554,063
SVE if Coupled with Focused Treatment Area Thermal	77,740	1,027	7,567,813	0.05	378,391	76	3.667	1,054,544
Hydraulic Displacement								
Without Groundwater Treatment	0	1,027	0	0.05	0	76	3.667	0

Notes:

[1] Source: U.S.D.O.E., Oak Ridge National Laboratory, Energy Conversions, http://bioenergy.ornl.gov/papers/misc/energy_conv.html

[2] Source: Engineering Toolbox and Online Conversion

[3] Source: U.S.E.P.A., *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*

[4] Calculated: Mass of CO_2 Released = (Mass Coal Consumed)x(Percent Carbon Content of Coal)x(Mass CO_2 Released per pound of Carbon)/100

BTU = British Thermal Unit

CF = Cubic Feet

CO_2 = Carbon Dioxide

lbs = Pounds

Table H-3
Carbon Footprint Analysis - Carbon Dioxide Emissions from On-Site Electricity Usage Generated from Natural Gas
Montrose Superfund Site

Remedial Technology	Electricity Usage	Electricity[1] Generated from Natural Gas	Natural Gas[2] Energy Content	Volume of Natural Gas Consumed	Density[3] of Natural Gas	Mass Natural Gas Consumed	Carbon[4] Content of Natural Gas	Mass CO_2 Released per pound of Carbon	Mass CO_2 Released[5,6]
	(KWh)	(%)	(BTUs/CF)	(CF)	(lbs/CF)	(lbs)	(%)	(lbs)	(lbs)
Steam Injection									
Full-Scale 2 UBA and 2.5 HF PVs - Lower Realistic	43,087,358	30	1,027	42,946,493	0.05	2,147,325	76	3.667	5,984,422
Full-Scale 3 UBA and 3.5 HF PVs - Upper Realistic	43,087,358	30	1,027	42,946,493	0.05	2,147,325	76	3.667	5,984,422
Average Full-Scale	-	-	-	-	-	-	-	-	-
Focused 2 UBA and 2.5 HF PVs - Lower Realistic	10,359,571	30	1,027	10,325,703	0.05	516,285	76	3.667	1,438,845
Focused 3 UBA and 3.5 HF PVs - Upper Realistic	10,359,571	30	1,027	10,325,703	0.05	516,285	76	3.667	1,438,845
Average Focused Treatment Area	-	-	-	-	-	-	-	-	-
ERH									
Full-Scale	110,987,358	30	1,027	110,624,509	0.05	5,531,225	76	3.667	15,415,083
Focused Treatment Area	21,829,145	30	1,027	21,757,779	0.05	1,087,889	76	3.667	3,031,860
SVE									
Stand Alone SVE	4,747,832	30	1,027	4,732,310	0.05	236,615	76	3.667	659,428
SVE if Coupled with Full-Scale Thermal	1,959,700	30	1,027	1,953,293	0.05	97,665	76	3.667	272,184
SVE if Coupled with Focused Treatment Area Thermal	3,919,399	30	1,027	3,906,585	0.05	195,329	76	3.667	544,367
Hydraulic Displacement									
Without Groundwater Treatment	4,369,805	30	1,027	4,355,519	0.05	217,776	76	3.667	606,924

Notes:

[1] Source: Cal. Energy Commission, LADWP Electricity Generation by Energy Source (Carbon impact from Nuclear (10%), Hydro (6%), and Renewable (6%) sources is assumed to be insignificant)

[2] Source: U.S.D.O.E., Oak Ridge National Laboratory, Energy Conversions, http://bioenergy.ornl.gov/papers/misc/energy_conv.html

[3] Source: Engineering Toolbox and Online Conversion

[4] Source: U.S.E.P.A., *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*

[5] Calculated: Mass of CO_2 Released = (Mass Coal Consumed)x(Percent Carbon Content of Coal)x(Mass CO_2 Released per pound of Carbon)/100

[6] This estimate does not include a life-cycle analysis of equipment used during project, nor emissions from machinery or vehicles used for treatment or obtaining natural resources

BTU = British Thermal Unit

CF = Cubic Feet

CO_2 = Carbon Dioxide

lbs = Pounds

Table H-4
Carbon Footprint Analysis - Carbon Dioxide Emissions from On-Site Electricty Usage Generated from Coal
Montrose Superfund Site

Remedial Technology	Electricity Usage	Electricity[1] Generated from Coal	Coal Energy[2] Content	Mass Coal Consumed	Carbon[2] Content of Coal	Mass CO_2[3] Released per pound of Carbon	Mass CO2 Released[4,5]
	(KWh)	(%)	(BTUs/lb)	(lbs)	(%)	(lbs)	(lbs)
Steam Injection							
2 UBA and 2.5 HF PVs - Lower Realistic	43,087,358	48	14,500	4,866,874	78	3.667	13,920,526
3 UBA and 3.5 HF PVs - Upper Realistic	43,087,358	48	14,500	4,866,874	78	3.667	13,920,526
Average Full-Scale	-	-	-	-	-	-	-
2 UBA and 2.5 HF PVs - Lower Realistic	10,359,571	48	14,500	1,170,151	78	3.667	3,346,937
3 UBA and 3.5 HF PVs - Upper Realistic	10,359,571	48	14,500	1,170,151	78	3.667	3,346,937
Average Focused Treatment Area	-	-	-	-	-	-	-
ERH							
Full-Scale	110,987,358	48	14,500	12,536,427	78	3.667	35,857,441
Focused Treatment Area	21,829,145	48	14,500	2,465,682	78	3.667	7,052,490
SVE							
Stand Alone SVE	4,747,832	48	14,500	536,285	78	3.667	1,533,914
SVE if Coupled with Full-Scale Thermal	1,959,700	48	14,500	221,355	78	3.667	633,134
SVE if Coupled with Focused Treatment Area Thermal	3,919,399	48	14,500	442,710	78	3.667	1,266,267
Hydraulic Displacement							
Without Groundwater Treatment	4,369,805	48	14,500	493,585	78	3.667	1,411,783

Notes:

[1] Source: Cal. Energy Commission, LADWP Electricity Generation by Energy Source (Carbon impact from Nuclear (10%), Hydro (6%), and Renewable (6%) sources is assumed to be insignificant)

[2] Source: U.S.D.O.E. Energy Information Administration, *Carbon Dioxide Emission Factors for Coal,* January-April 1994

[3] Source: U.S.D.O.E. Oak Ridge National Laboratory, Energy Conversions, http://bioenergy.ornl.gov/papers/misc/energy_conv.html

[4] Calculated: Mass of CO_2 Released = (Mass Coal Consumed)x(Percent Carbon Content of Coal)x(Mass CO_2 Released per pound of Carbon)/100

[5] This estimate does not include a life-cycle analysis of equipment used during project, nor emissions from machinery or vehicles used for treatment or obtaining natural resources

BTU = British Thermal Unit

CF = Cubic Feet

CO_2 = Carbon Dioxide

lbs = Pounds

Appendix I

Technical Memorandum RE: Energy Balance for the Full-Scale Steam Injection Remedial Alternative

EARTH TECH | AECOM

300 Oceangate
Suite 700
Long Beach, CA 90802

T 562.951.2000
F 562.951.2100
www.earthtech.com

Memo

September 24, 2008

To: Joe Kelly, Karl Lytz, Kelly Richardson, Paul Sundberg, and Mike Palmer

From: Jacob Barnes and Brian Dean, Earth Tech, Inc., Long Beach, CA
Dacre Bush, TN & Associates, Inc.

Subject: Energy Balance for the Full-Scale Steam Injection Remedial Alternative, DNAPL Feasibility Study, Montrose Superfund Site, Torrance, California

Introduction

The purpose of this memorandum is to estimate the energy balance for thermal remediation of dense non-aqueous phase liquid (DNAPL) at the Montrose Superfund Site (Site). Steam injection is one of the two thermal remedial alternatives being considered by the DNAPL Feasibility Study (FS), and Montrose submitted a cost evaluation for a full-scale steam injection remedial alternative to EPA on July 21, 2008. That cost evaluation had assumed sufficient steam to flush the target volume within the Upper Bellflower Aquitard (UBA) with 3 pore volumes (PVs, cold water equivalent) and the Bellflower Sand (BFS) hot floor with 5 PVs. EPA commented on the cost evaluation in an email dated August 8, 2008, and requested that reduced energy demand assumptions be used to estimate steam injection costs, specifically 2 PVs in both the UBA and BFS hot floor. In a meeting on September 11, 2008, EPA additionally requested that Montrose prepare an energy balance for the full-scale steam injection remedial alternative to evaluate how much energy is realistically required to heat the saturated zone. This memorandum presents the energy balance estimate prepared in response to EPA's request and recommends a path forward for resolving thermal remediation costs in support of the DNAPL FS.

Basic Energy Demand

The basic energy demand for heating the saturated zone was defined in the Doctoral Thesis *A Critical Evaluation of In-Situ Thermal Technologies* by Jennifer Lake Triplett Kingston using the following equation:

$$E = (m_{soil} \times Cp_{soil} \times dT) + (m_{water} \times Cp_{water} \times dT) + (m_{water} \times dH_{water})$$

E = Energy demand
m_{soil} = Soil mass (lbs)
m_{water} = Water mass (lbs)
Cp_{soil} = Soil heat capacity (J/lb-°C)
Cp_{water} = Water heat capacity (J/lb-°C)
dT = Change in temperature (°C)
dH_{water} = Water heat of vaporization (J/lb)

The following thermodynamic constants and assumptions were used to derive the basic energy demand for the Montrose Superfund Site:

- Soil heat capacity = 362.9 J/lb-°C (Engineering ToolBox.com)
- Water heat capacity = 1,897.8 J/lb-°C (Perry's Chemical Engineering Handbook)
- Water heat of vaporization = 1,029,665 J/lb (Engineering ToolBox.com)
- Temperature rise = 80°C (from 20 to 100°C)
- Percent of water displaced by steam (rather than heated) = 25% in both UBA and BFS
- Soil density = 120 lbs/cu ft
- Soil porosity (effective) = 29%
- Water density = 8.32 lbs/gal

Using the above assumptions, the amount of energy required to heat one cubic yard (CY) of saturated soil in either the UBA or BFS was estimated to be 498,253 BTUs as shown in **Table 1** and **Attachments 1 and 2**. The required steam mass to meet this energy demand is 511 pounds, which is equivalent to 1.05 pore volumes (cold water equivalent). However, this calculation does not account for energy/heat losses in the system.

Energy Losses

Energy/heat losses occur throughout the steam injection remedy including at the boiler, aboveground piping losses, in-situ inefficiencies in steam delivery (e.g., preferential permeability), heat losses to surrounding formations, and heat removal at the extraction wells. All of the losses contribute to the energy demand required to initially heat the soil to 100°C. A summary of the assumed energy/heat losses is provided as follows:

- Boiler efficiency (see **Attachment 3** for specifications from Nationwide Boiler; 28,800 scfh natural gas yields 19,125 lbs/hr of steam at 125 psig)
- Aboveground line losses, including wellhead (7% loss; estimated by McMillan-McGee)
- Losses to areas outside the treatment area (23% in UBA and 22% in BFS; based on well patterns from July 21 Montrose cost evaluation)
- Losses to the vadose zone (11%; only applies to UBA)
- Losses due to heat removal at extraction wells (39% in UBA and 17% in BFS; see Attachments 1 and 2 for details)
- Losses below the hot floor (50%; only applies to BFS)
- Losses due to groundwater influx (1%; only applies to BFS)

The resulting total energy/heat losses are 134% and 152% of the basic energy demand for the UBA and BFS hot floor respectively. Therefore, to heat the saturated zone by 80°C, the amount of energy required is:

UBA = 498,253 BTUs/CY x 2.34 = 1,166,401 BTUs/CY

BFS = 498,253 BTUs/CY x 2.52 = 1,253,282 BTUs/CY

This is the amount of energy required at the meter to heat one CY by 80°C. However, the above energy demand assumes that the thermal project would be terminated upon reaching temperature. Assuming two 29 MM BTUs/hr steam boilers for the full-scale steam remedy, the UBA and BFS hot floor would reach target temperature after just 225 and 54 days respectively (including assumed losses). Note that this is a reduction in the number of boilers since three boilers were assumed for the July 21 cost evaluation. Continued thermal treatment will occur in the UBA after 225 days in order to effectively flush/volatilize the DNAPL from the treatment volume, and the BFS hot floor must continue to be heated throughout treatment in the overlying UBA. The energy demand during the O&M phase, after reaching target temperature, is estimated in the following section.

Energy Demand During Pressure Cycling

EPA has concurred with the assumed 2-year duration of the full-scale steam injection scenario but indicated that pressure cycling would be employed to reduce the energy demand. Accordingly, the energy demand during the remainder of the O&M phase was estimated using the following assumptions:

- Duration = 505 days in the UBA (24 months – 225 days) and 706 days in the BFS hot floor (25 months – 54 days)
- Energy delivery capacity = 82% in the UBA and 18% in the BFS from two 28.8 MM BTUs/hr steam boilers (based on ratio of treatment volumes)
- Energy demand savings due to pressure cycling = 25%

The resulting energy delivery during the remainder of the two year O&M phase is 428,398 MM BTUs or 1,606,493 BTUs/CY in the UBA. This energy demand is equivalent to 1.44 PVs of steam flushing (cold water equivalent). In the BFS hot floor, the energy demand to complete 2 years of O&M is 133,129 MM BTUs or 2,246,649 BTUs/CY, which is equivalent to 1.88 PVs.

Total Energy Demand

Combining the basic energy demand, the assumed energy/heat losses, and the energy demand during the remainder of the 2-year O&M phase, the following total energy demand is estimated for the full-scale steam injection remedy:

Energy Category	BTUs/CY	MM BTUs	PV Equivalent
UBA			
Basic Energy Demand	498,253	132,867	1.05
Energy/Heat Losses	668,148	178,173	---
Remainder O&M	1,606,493	428,398	1.44
Total Energy Demand	**2,772,894**	**739,438**	**2.49**
BFS Hot Floor			
Basic Energy Demand	498,253	29,526	1.05
Energy/Heat Losses	755,029	44,742	---
Remainder O&M	2,246,549	133,129	1.88
Total Energy Demand	**3,499,831**	**207,397**	**2.93**

Comparison with Existing Cost Estimates

On July 21, 2008, a Full-Scale Steam Injection Cost Evaluation was submitted to EPA. That evaluation assumed 3 PVs steam flushing in the UBA and 5 PVs in the BFS hot floor. The energy demand in that estimate was 3.91 MM BTUs/CY, excluding the amount of steam required for the regenerable carbon system for the combined UBA and BFS hot floor. EPA had subsequently requested that costs be re-estimated assuming less steam flushing. Accordingly, Earth Tech estimated steam injection costs assuming 2 PVs in the UBA and 3 PVs in the BFS hot floor, and the resulting energy demand was 2.3 MM BTUs/CY.

The combined energy demand from the energy balance calculations is 2.91 MM BTUs/CY. The existing low cost scenario assumes 21% less energy than this value, and the existing high cost scenario assumes 34% more energy than this value. The assumed energy consumption in the UBA, 2 to 3 PVs, effectively brackets the target energy balance of 2.49 PVs. However, the assumed energy consumption in the BFS hot floor, 3 to 5 PVs, does not bracket the target energy balance of 2.93 PVs.

Comparison with Other Steam Injection Sites

The energy consumed at two completed steam injection projects was evaluated for comparison purposes. For the Port of Ridgefield Site, an energy demand of 2.9 MM BTUs/CY was reported during Phase 1 of the steam injection remedy (*Interim/Emergency Action Phase 2 Design Report*, Port of Ridgefield Lake River Industrial Site Agreed Order 01TCPSR-3119, Steam-Enhanced Remediation Project, October 7, 2005, Maul Foster & Alongi [MFA], Inc.). In a telephone interview on September 15, 2008, Mr. Steven Taylor of MFA indicated that the energy demand observed during Phase 1 of the steam injection remedy was **1,100** kw-hrs/m3, which is equivalent to 2.9 MM BTUs/CY. The energy demand from the Port of Ridgefield Site is nearly identical to the estimated energy balance for the Montrose Site (2.9 vs 2.93 MM BTUs/CY).

For the Unocal Guadalupe Site, an energy demand of 4.2 MM BTUs/CY was reported (*Final Hot Water/Steam Injection Report*, Unocal Guadalupe Restoration Project, Guadalupe, California, May 2004, Haley & Aldrich). Propane was the source fuel used to generate steam for the Unocal Guadalupe Site, and the above energy demand is based on 25% of the total propane usage. Since the target area was treated by a single 5-spot pattern (4 steam injection wells at the corners), only 25% of the steam would have been delivered inside the target treatment area. The energy demand for the Unocal Guadalupe Site is approximately 7% higher than the higher cost scenario for the Montrose Site.

Recommendations

EPA is proposing to use the energy balance to establish scoping assumptions for the low and high cost steam injection scenarios. The estimated energy balance for the Montrose Site is nearly identical to the value determined at the Port of Ridgefield Site, which is similar in size although different in contaminant type and lithology. Therefore, the Montrose Site energy balance is considered a reasonable value for purposes of establishing a reasonable range of thermal remedy costs.

For the low and high cost scenarios for the Montrose Site, it is recommended that energy demands below and above the target energy balance be assumed in order to provide a reasonable range of energy costs. The existing cost estimates already serve to provide such a range, 2.3 to 3.9 MM

BTUs/CY treated, relative to the target energy balance of 2.9 MM BTUs/CY. However, the energy consumption assumed for the BFS hot floor in the cost estimates, 3 to 5 PVs, exceeds the target energy balance of 2.93 PVs. Therefore, a small adjustment to the energy demand assumptions for the low and high cost scenarios is recommended as follows:

Treatment Unit	Low Cost Scenario	Target Energy Balance	High Cost Scenario
UBA	2 PVs	2.49 PVs	3 PVs
BFS Hot Floor	2.5 PVs	2.93 PVs	3.5 PVs

Attachments

Table 1 – Steam Injection Energy Balance Summary
Attachment 1 – Energy Balance Calculations for the UBA
Attachment 2 – Energy Balance Calculations for the BFS Hot Floor
Attachment 3 – Steam Boiler Specification Sheet from Nationwide Boiler

Table 1
Energy Balance Summary for Full-Scale Steam Injection
Montrose Superfund Site

Energy to Reach Target Subsurface Temperature	**Upper Bellflower Aquitard**		**Hot-Floor (Bellflower Sand)**	
Basic Unit Rate Energy Demand (Losses Not Included)	498,253	BTUs/CY	498,253	BTUs/CY
Unit Rate Energy Demand Including Losses	1,166,401	BTUs/CY	1,253,282	BTUs/CY
Total Energy Demand	311,040	MMBTUs	74,269	MMBTUs
Pore Volumes of Steam	1.05	PVs	1.05	PVs
Duration	225	Days[1]	54	Days[1]

Energy for Pressure Cycling

Total Duration	505	Days[2]	706	Days[2]
Unit Rate Energy Demand	1,606,493	BTUs/CY	2,246,549	BTUs/CY
Total Energy Demand	428,398	MMBTUs	133,129	MMBTUs
Pore Volumes of Steam Delivered	1.44	PVs	1.88	PVs

Total Energy (Reach Subsurface Temp and Conduct Pressure Cycling)

Unit Rate Energy Demand Including Losses	2,772,894	BTUs/CY	3,499,831	BTUs/CY
Total Energy Demand	739,438	MMBTUs	207,397	MMBTUs
Pore Volumes of Steam	2.49	PVs	2.93	PVs

Notes:
1 = Assumes two 28.8MMBTUs/Hr steam boilers operating continuously
2 = Assumes a total O&M duration of 2 years in the UBA (30 additional days for the Hot-Floor) minus time required to reach target subsurface temperature.

Attachment 1
Upper Bellflower Aquitard

Energy Demand Equation

$E = (m_{soil} \times Cp_{,soil} \times dT) + (m_{water} \times Cp_{,water} \times dT) + (m_{water} \times dH_{water})$

Source: A Critical Evaluation of In-Situ Thermal Technologies, Jennifer Lake Triplett Kingston

Basic Energy Demand for One Cubic Yard of Saturated Soil

Fraction of groundwater displaced by injected steam =	0.25	
m_{soil} =	3240	lbs
m_{water} =	365	lbs
E =	525,685	KJ
	498,253	BTU
Required Steam Mass =	511	lbs
Required Steam Volume (cold water equivs) =	0.30	CY
One Pore Volume =	0.29	CY
Required Pore Volumes of Steam (cold water equivs) =	**1.05**	

Energy Losses

Boiler Efficiency =	46%	
Aboveground line losses =	7%	McMillan McGee
Losses to surrounding Areas =	23%	Earth Tech July 2008 Steam Injection Cost Evaluation
Losses to Vadose Zone Above =	11%	
Losses due to heat removal at extraction wells =	39%	
Total Losses =	134%	

Energy Demand Including Losses

E =	**1,166,401**	BTUs/CY
Total Energy Demand =	311,040	MMBTUs
	3,110,404	Therms
Natural Gas Unit Cost =	$ 1.14	/Therm
Total Undiscounted Cost =	**$ 3,545,860**	

Constants

Soil Heat Capacity ($Cp_{,soil}$) =	362.9	J/(lb-C)	Online source: EngineeringToolBox.com
Water Heat Capacity ($Cp_{,water}$) =	1,897.8	J/(lb-C)	Perry's Chemical Engineering Handbook, Sixth Edition
Heat of Vaporization of Water (dH_{water}) =	1,029,665	J/lb	Online source: EngineeringToolBox.com
Soil Density =	120	lbs/CF	
Water/Steam Density (cold water equivalent) =	8.32	lbs/Gal	

28.8 MMBTUs/Hr Boiler Performance (Nationwide Boiler)

Case Condition: 0% Condensate Return

19,125 lbs steam per 28,800 SCF Natural Gas =

1,588,790 J/lb

Boiler Efficiency = 46%

UBA Treatment Area Parameters

UBA Groundwater Temp =	20	C	2006 Groundwater Monitoring Results Report, Montrose Site, Torrance, California, Hargis + Associates, Inc.
Assumed UBA Soil Temp =	20	C	
Target Subsurface Temp =	100	C	
Target Temp Increase (dT) =	80	C	
Subsurface Porosity =	0.29		
Treatment Area =	160,000	SF	
UBA Treatment Interval =	45	Feet	
UBA Treatment Volume =	7,200,000	CF	
	266,667	CY	

Vadose Zone

Capillary Fringe Interval =	5	Feet
Heated Capillary Fringe Volume =	800,000	CF
	29,630	CY

Extraction Wells

Temperature of extracted water =	80	C	
Extraction Rate per Well =	2.5	GPM	
Number of Extraction Wells =	53		
Total Extraction Rate =	133	GPM	
	7,950	Gals/Hr	
	66,113	lbs/Hr	
Enthalpy of extracted water =	334.9	KJ/Kg	Introduction to Chemical Engineering Thermodynamics, Sixth Edition, Table F.1: Saturated Steam
	144	BTU/lb	
Total Energy Removal Rate =	9,519,174	BTUs/Hr	
Assumed operating duration to get to temp =	225	Days	
Total Energy Removed during operation =	51,401	MMBTUs	
Energy Removed per Cubic Yard of Soil =	192,752	BTUs/CY	

Attachment 2
Hot Floor - Bellflower Sand

Energy Demand Equation

$E = (m_{soil} X\ Cp_{,soil} X\ dT) + (m_{water} X\ Cp_{,water} X\ dT) + (m_{water} X\ dH_{water})$ Source: A Critical Evaluation of In-Situ Thermal Technologies, Jennifer Lake Triplett Kingston

Basic Energy Demand for One Cubic Yard of Saturated Soil

Fraction of groundwater displaced by injected steam =	0.25	
m_{soil} =	3240	lbs
m_{water} =	365	lbs
E =	525,685	KJ
	498,253	BTU
Required Steam Mass =	511	lbs
Required Steam Volume (cold water equivs) =	0.30	CY
One Pore Volume =	0.29	CY
Required Pore Volumes of Steam (cold water equivs) =	**1.05**	

Energy Losses

Boiler Efficiency =	46%	
Aboveground line losses =	7%	McMillan McGee
Losses to surrounding Areas =	22%	55 total steam injection wells including 20 outer injection wells. Only 50% of steam injected in outer wells is lost to surrounding areas.
Losses Below Hot Floor =	50%	
Losses due to heat removal at extraction wells =	17%	
Losses due to cooling effects of flowing groundwater =	1%	
Total Losses =	152%	

Energy Demand Including Losses

E =		**1,253,282**	BTUs/CY
Total Energy Demand =		74,269	MMBTUs
		742,686	Therms
Natural Gas Unit Cost =	$	1.14	/Therm
Total Undiscounted Cost =	**$**	**846,662**	

Constants

Soil Heat Capacity ($Cp_{,soil}$) =	362.9	J/(lb-C)	Online source: EngineeringToolBox.com
Water Heat Capacity ($Cp_{,water}$) =	1,897.8	J/(lb-C)	Perry's Chemical Engineering Handbook, Sixth Edition
Heat of Vaporization of Water (dH_{water}) =	1,029,665	J/lb	Online source: EngineeringToolBox.com
Soil Density =	120	lbs/CF	
Water/Steam Density (cold water equivalent) =	8.32	lbs/Gal	

28.8 MMBTUs/Hr Boiler Performance (Nationwide Boiler)

Case Condition 0% Condensate Return

19,125 lbs steam per	28,800	SCF Natural Gas =
1,588,790 J/lb		
Boiler Efficiency =	46%	

Hot Floor Parameters (Bellflower Sand [BFS])

BFS Groundwater Temp =	20	C	2006 Groundwater Monitoring Results Report, Montrose Site, Torrance, California, Hargis +
Assumed BFS Soil Temp =	20	C	
Target Subsurface Temp =	100	C	
Target Temp Increase (dT) =	80	C	
Subsurface Porosity =	0.29		
Hot Floor Area =	160,000	SF	
Hot Floor Interval =	10	Feet	
Hot Floor Volume =	1,600,000	CF	
	59,259	CY	

Below Hot-Floor

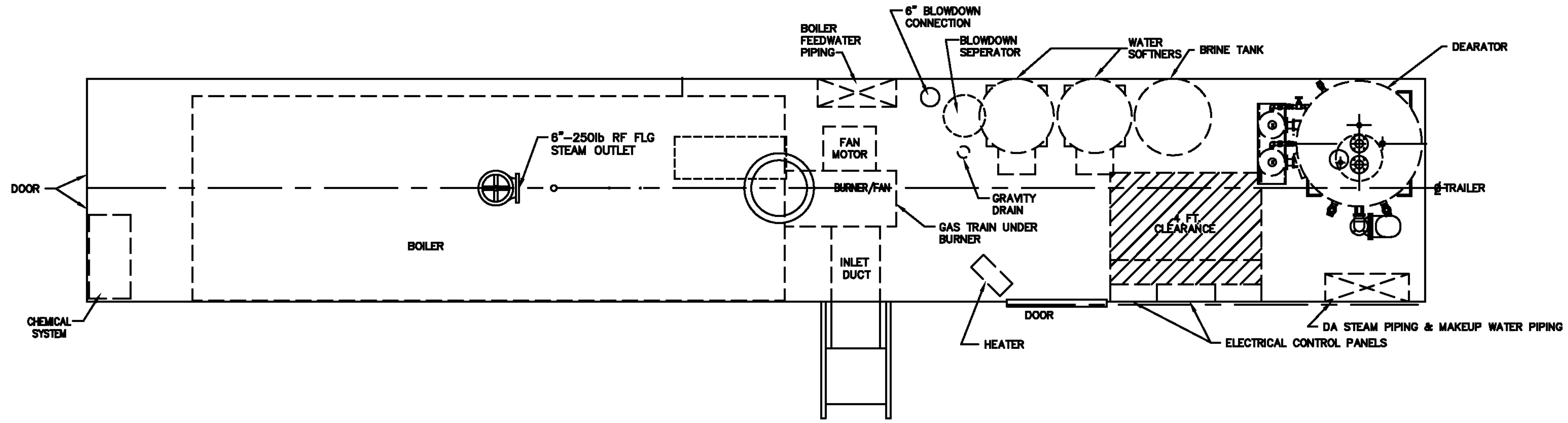
Interval Below Hot Floor =	5	Feet
Heated Volume Below Hot Floor =	800,000	CF
	29,630	CY

Extraction Wells

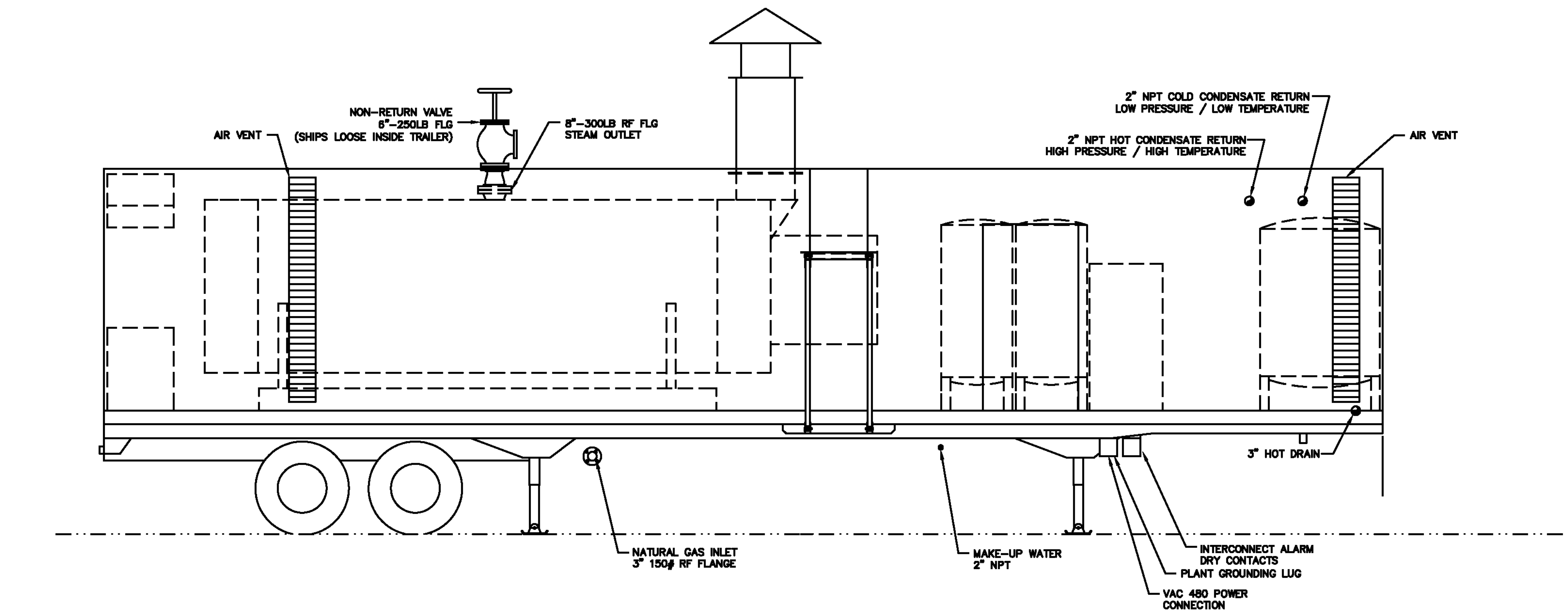
Temperature of extracted water =	80	C	
Extraction Rate per Well =	2.5	GPM	
Number of Extraction Wells =	22		
Total Extraction Rate =	55	GPM	
	3,300	Gals/Hr	
	27,443	lbs/Hr	
Enthalpy of extracted water =	334.9	KJ/Kg	Introduction to Chemical Engineering Thermodynamics, Sixth Edition, Table F.1:
	144	BTU/lb	
Total Energy Removal Rate =	3,951,355	BTUs/Hr	
Assumed operating duration to get to temp =	54	Days	
Total Energy Removed during operation =	5,100	MMBTUs	
Energy Removed per Cubic Yard of Soil =	86,064	BTUs/CY	

Cooling Effects of Flowing Groundwater

Temperature of groundwater entering hot floor =	20	C	2006 Groundwater Monitoring Results Report, Montrose Site, Torrance, California, Hargis + Associates, Inc.
Target Groundwater Temp =	100	C	
Target Temp Increase (dT) =	80	C	
Average BFS hydraulic conductivity =	207	Feet/Day	Final Remdial Investigation Report for the Montrose Superfund Site, Los Angeles, California, Montrose Chemical Corporation
Average BFS hydraulic gradient =	0.00055		2006 Groundwater Monitoring Results Report, Montrose Site, Torrance, California, Hargis + Associates, Inc.
Approximate coss-sectional length of hot floor perpendicular to groundwater gradient =	380	Feet	
Velocity of infiltrating groundwater =	0.39	Feet/Day	
Volume of groundwater infiltrating hot floor per day =	433	CF/Day	
	3,236	Gal/Day	
Total Volume of infiltrated groundwater =	174,049	Gals	
Volume of infiltrated groundwater per cubic yard of soil =	3	Gals/CY	
Volume of infiltrated groundwater to be heated =	2	Gals/CY	
Energy Demand for heating =	5,049	KJ/CY	
	4,786	BTUs/CY	



PLAN



ELEVATION (CURB SIDE SHOWN)

650HP MOBILE BOILER ROOM

STEAM PERFORMANCE NOTE 1

STEAM FLOW (NET)	— 19,125 LBS/HR	NOTE 2
OPERATING PRESSURE	— 125–225 PSIG	

BOILER PERFORMANCE

STEAM FLOW (GROSS)	— 22,400 LBS/HR
DESIGN PRESS	— 250 PSIG

FUEL REQUIREMENTS:

NATURAL GAS

FLOW	— 28,800 -SCFH
PRESSURE	— 12 PSIG
	8 PSIG (MIN.)

MAKEUP WATER REQUIREMENTS

NORMAL OPERATION

FLOW	— 71.5 GPM NOTE 2
PRESSURE	— 60–100 PSIG
TEMPERATURE	— 60–100 F

HOT CONDENSATE RETURN REQUIREMENTS

PRESSURE	— 40–100 PSIG
TEMPERATURE	— 180–200 F

COLD CONDENSATE RETURN REQUIREMENTS

PRESSURE	— 40–100 PSIG
TEMPERATURE	— 60–179 F

EMISSIONS (NATURAL GAS):

NOx	— 9 PPM
CO	— 50 PPM

ELECTRICAL POWER REQUIREMENTS

460 VAC, 3PH, 60 HZ — 150 AMPS

SHIPPING WEIGHT: — 68,000 LBS

OPERATING WEIGHT: — 116,900 LBS

CONNECTION SCHEDULE

B	— BLOWDOWN	6"-150# RF FLG
C	— CONDENSATE RETURN	2" NPT
D	— GRAVITY DRAIN	2" NPT
N	— NATURAL GAS SUPPLY	3"-150# RF FLG
S	— STEAM NRV VALVE	6"-250# RF FLG
W	— MAKEUP WATER	2" NPT

NOTES:

1. SYSTEM PERFORMANCE IS BASED ON OPERATION AT 1000' OR LESS ELEVATION AND AT CONDITIONS NOTED BELOW.
2. CONDITIONS INCLUDE 0% CONDENSATE RETURN
3. EMISSIONS ARE BASED ON NORMAL OPERATION

REV.	DATE	DESCRIPTION
3	12/03/04	UPDATED STEAM OUTLET

CONTRACT NO. B552

APPROVALS	DATE
DRAWN	
DESIGN	
CHECKED	
ISSUED	

Nationwide Boiler Incorporated 42400 Christy Street • Fremont, California 94538-3141 510/490-7100 • 800/227-1966 • FAX 510/490-0571

MOBILE BOILER ROOM
22,400 PPH
GENERAL ARRANGEMENT

SIZE	FSCM NO.	DWG. NO.	REV.
D		B552-GA-01	3

SCALE NONE | FILE NAME B552-GA-01 | SHEET 1 OF 1

Appendix J

Remedial Alternatives Cost Summaries and Detailed Cost Tables

Appendix J
Remedial Alternatives Cost Summary
Draft DNAPL Feasibility Study
Montrose Superfund Site, Torrance, California

Remedial Alternative (RA)	General Response Actions (GRAs)	Cost Summary Table	Cost (NPV)
1 - No Action	No Action for DNAPL	NA	$ -
	Long-Term Hydraulic Containment	Table 1.0	$ 1,102,711
		Total	**$ 1,102,711**
2 - Institutional Controls	Long-Term Hydraulic Containment	Table 1.0	$ 1,102,711
	Institutional Controls	Table 2.0	$ 192,229
		Total	**$ 1,294,940**
3 - SVE in the Unsaturated Zone	Long-Term Hydraulic Containment	Table 1.0	$ 1,102,711
	Institutional Controls	Table 2.0	$ 192,229
	SVE in the Unsaturated Zone	Table 3.0	$ 4,630,281
		Total	**$ 5,925,221**
4 - Hydraulic Displacement with Untreated Water Injection (50-Foot Well Spacing - Low Cost)	Long-Term Hydraulic Containment	Table 1.0	$ 1,102,711
	Institutional Controls	Table 2.0	$ 192,229
	SVE in the Unsaturated Zone	Table 3.0	$ 4,630,281
	Hydraulic Displacement with Untreated Water Re-Injection	Table 4.0	$ 5,805,919
		Total	**$ 11,731,140**
4 - Hydraulic Displacement with Untreated Water Injection (25-Foot Well Spacing - High Cost)	Long-Term Hydraulic Containment	Table 1.0	$ 1,102,711
	Institutional Controls	Table 2.0	$ 192,229
	SVE in the Unsaturated Zone	Table 3.0	$ 4,630,281
	Hydraulic Displacement with Untreated Water Re-Injection	Table 5.0	$ 7,108,187
		Total	**$ 13,033,408**
5A - Steam Injection over Focused Treatment Area (2 UBA Pore Volumes and 2.5 Hot Floor Pore Volumes - Low Cost)	Long-Term Hydraulic Containment	Table 1.0	$ 1,102,711
	Institutional Controls	Table 2.0	$ 192,229
	SVE in the Unsaturated Zone	Table 6.0	$ 2,521,673
	Steam Injection over Focused Treatment Area	Table 7.0	$ 20,788,672
		Total	**$ 24,605,285**
5A - Steam Injection over Focused Treatment Area (3 UBA Pore Volumes and 3.5 Hot Foor Pore Volumes - High Cost)	Long-Term Hydraulic Containment	Table 1.0	$ 1,102,711
	Institutional Controls	Table 2.0	$ 192,229
	SVE in the Unsaturated Zone	Table 6.0	$ 2,521,673
	Steam Injection over Focused Treatment Area	Table 8.0	$ 22,023,207
		Total	**$ 25,839,820**
6A - ERH over Focused Treatment Area (No Additional Heating - Low Cost)	Long-Term Hydraulic Containment	Table 1.0	$ 1,102,711
	Institutional Controls	Table 2.0	$ 192,229
	SVE in the Unsaturated Zone	Table 6.0	$ 2,521,673
	ERH over Focused Treatment Area	Table 9.0	$ 17,376,453
		Total	**$ 21,193,066**
6A - ERH over Focused Treatment Area (70 kw-hrs/cubic yard of Additional Heating - High Cost)	Long-Term Hydraulic Containment	Table 1.0	$ 1,102,711
	Institutional Controls	Table 2.0	$ 192,229
	SVE in the Unsaturated Zone	Table 6.0	$ 2,521,673
	ERH over Focused Treatment Area	Table 9.0	$ 17,376,453
		Table 10.0	$ 1,734,313
		Total	**$ 22,927,379**

Appendix J
Table 1.0
Cost Summary
Long-Term Hydraulic Containment

Discount Rate 4%

Activity	Detailed Cost Table	Cost (Undiscounted)	Cost (NPV)
Annual Operations and Maintenance	J-1.1 Annual Operations and Maintenance - NPV Analysis	$ 861,593,285	$ 848,999
Well Rehabilitation Once Every 2 Years	J-1.3 Well Rehabilitation - NPV Analysis	$ 81,476,325	$ 81,860
Well Equipment Replacement			
Well Pump and Controls Replacement Once Every 2 Years	J-1.5 Well Pump and Controls Replacement - NPV Analysis	$ 59,726,100	$ 60,007
Well Assembly Replacement Once Every 5 Years	J-1.7 Well Assembly Replacement - NPV Analysis	$ 12,341,847	$ 13,134
Major System Component Replacement			
Treatment Equipment Replacement Once Every 20 Years	J-1.9 Treatment Equipment Replacement - NPV Analysis	$ 19,116,233	$ 12,131
Well Replacement Once Every 20 Years	J-1.11 Well Replacement - NPV Analysis	$ 136,437,513	$ 86,581

Total NPV Cost	$ 1,102,711
Total Undiscounted Cost[1]	$ 1,170,691,304

Notes:

[1] The total undiscounted cost shown is for long-term hydraulic containment from years 51 to 3620 following 50 years of pump and treat for groundwater and full-scale thermal treatment for DNAPL. Focused area thermal treatment, hydraulic displacement, and hydraulic containment for DNAPL result in approximate long-term hydraulic containment durations lasting until years 4360, 4650, and 4890, respectively. Though the undiscounted cost of long-term hydraulic containment will be greater for the less aggressive DNAPL remedies, the NPV cost will not change due to the incedibly long durations of all four scenarios.

Appendix J
Table 1.1
Detailed Cost, Hydraulic Containment
Annual Operations and Maintenance - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
51	$ 241,343	$ 32,654
52	$ 241,343	$ 31,398
53	$ 241,343	$ 30,190
54	$ 241,343	$ 29,029
55	$ 241,343	$ 27,913
56	$ 241,343	$ 26,839
57	$ 241,343	$ 25,807
58	$ 241,343	$ 24,814
59	$ 241,343	$ 23,860
60	$ 241,343	$ 22,942
61	$ 241,343	$ 22,060
62	$ 241,343	$ 21,211
63	$ 241,343	$ 20,395
64	$ 241,343	$ 19,611
65	$ 241,343	$ 18,857
66	$ 241,343	$ 18,131
67	$ 241,343	$ 17,434
68	$ 241,343	$ 16,764
69	$ 241,343	$ 16,119
70	$ 241,343	$ 15,499
71	$ 241,343	$ 14,903
72	$ 241,343	$ 14,330
73	$ 241,343	$ 13,778
74	$ 241,343	$ 13,249
75	$ 241,343	$ 12,739
76	$ 241,343	$ 12,249
77	$ 241,343	$ 11,778
78	$ 241,343	$ 11,325
79	$ 241,343	$ 10,889
80	$ 241,343	$ 10,470
81	$ 241,343	$ 10,068
82	$ 241,343	$ 9,681
83	$ 241,343	$ 9,308
84	$ 241,343	$ 8,950
85	$ 241,343	$ 8,606
86	$ 241,343	$ 8,275
87	$ 241,343	$ 7,957
88	$ 241,343	$ 7,651
89	$ 241,343	$ 7,356
90	$ 241,343	$ 7,073
91	$ 241,343	$ 6,801
92	$ 241,343	$ 6,540
93	$ 241,343	$ 6,288
94	$ 241,343	$ 6,046
95	$ 241,343	$ 5,814
96	$ 241,343	$ 5,590
97	$ 241,343	$ 5,375
98	$ 241,343	$ 5,169

Appendix J
Table 1.1
Detailed Cost, Hydraulic Containment
Annual Operations and Maintenance - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
99	$ 241,343	$ 4,970
100	$ 241,343	$ 4,779
101	$ 241,343	$ 4,595
102	$ 241,343	$ 4,418
103	$ 241,343	$ 4,248
104	$ 241,343	$ 4,085
105	$ 241,343	$ 3,928
106	$ 241,343	$ 3,777
107	$ 241,343	$ 3,631
108	$ 241,343	$ 3,492
109	$ 241,343	$ 3,357
110	$ 241,343	$ 3,228
111	$ 241,343	$ 3,104
112	$ 241,343	$ 2,985
113	$ 241,343	$ 2,870
114	$ 241,343	$ 2,760
115	$ 241,343	$ 2,653
116	$ 241,343	$ 2,551
117	$ 241,343	$ 2,453
118	$ 241,343	$ 2,359
119	$ 241,343	$ 2,268
120	$ 241,343	$ 2,181
121	$ 241,343	$ 2,097
122	$ 241,343	$ 2,016
123	$ 241,343	$ 1,939
124	$ 241,343	$ 1,864
125	$ 241,343	$ 1,793
126	$ 241,343	$ 1,724
127	$ 241,343	$ 1,657
128	$ 241,343	$ 1,594
129	$ 241,343	$ 1,532
130	$ 241,343	$ 1,473
131	$ 241,343	$ 1,417
132	$ 241,343	$ 1,362
133	$ 241,343	$ 1,310
134	$ 241,343	$ 1,259
135	$ 241,343	$ 1,211
136	$ 241,343	$ 1,164
137	$ 241,343	$ 1,120
138	$ 241,343	$ 1,077
139	$ 241,343	$ 1,035
140	$ 241,343	$ 995
141	$ 241,343	$ 957
142	$ 241,343	$ 920
143	$ 241,343	$ 885
144	$ 241,343	$ 851
145	$ 241,343	$ 818
146	$ 241,343	$ 787

Appendix J
Table 1.1
Detailed Cost, Hydraulic Containment
Annual Operations and Maintenance - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
147	$ 241,343	$ 756
148	$ 241,343	$ 727
149	$ 241,343	$ 699
150	$ 241,343	$ 672
151	$ 241,343	$ 647
152	$ 241,343	$ 622
153	$ 241,343	$ 598
154	$ 241,343	$ 575
155	$ 241,343	$ 553
156	$ 241,343	$ 531
157	$ 241,343	$ 511
158	$ 241,343	$ 491
159	$ 241,343	$ 472
160	$ 241,343	$ 454
161	$ 241,343	$ 437
162	$ 241,343	$ 420
163	$ 241,343	$ 404
164	$ 241,343	$ 388
165	$ 241,343	$ 373
166	$ 241,343	$ 359
167	$ 241,343	$ 345
168	$ 241,343	$ 332
169	$ 241,343	$ 319
170	$ 241,343	$ 307
171	$ 241,343	$ 295
172	$ 241,343	$ 284
173	$ 241,343	$ 273
174	$ 241,343	$ 262
175	$ 241,343	$ 252
176	$ 241,343	$ 243
177	$ 241,343	$ 233
178	$ 241,343	$ 224
179	$ 241,343	$ 216
180	$ 241,343	$ 207
181	$ 241,343	$ 199
182	$ 241,343	$ 192
183	$ 241,343	$ 184
184	$ 241,343	$ 177
185	$ 241,343	$ 170
186	$ 241,343	$ 164
187	$ 241,343	$ 158
188	$ 241,343	$ 151
189	$ 241,343	$ 146
190	$ 241,343	$ 140
191	$ 241,343	$ 135
192	$ 241,343	$ 129
193	$ 241,343	$ 125
194	$ 241,343	$ 120

BOE-C6-0060097

Appendix J
Table 1.1
Detailed Cost, Hydraulic Containment
Annual Operations and Maintenance - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
195	$ 241,343	$ 115
196	$ 241,343	$ 111
197	$ 241,343	$ 106
198	$ 241,343	$ 102
199	$ 241,343	$ 98
200	$ 241,343	$ 95
201	$ 241,343	$ 91
202	$ 241,343	$ 87
203	$ 241,343	$ 84
204	$ 241,343	$ 81
205	$ 241,343	$ 78
206	$ 241,343	$ 75
207	$ 241,343	$ 72
208	$ 241,343	$ 69
209	$ 241,343	$ 66
210	$ 241,343	$ 64
211	$ 241,343	$ 61
212	$ 241,343	$ 59
213	$ 241,343	$ 57
214	$ 241,343	$ 55
215	$ 241,343	$ 53
216	$ 241,343	$ 51
217	$ 241,343	$ 49
218	$ 241,343	$ 47
219	$ 241,343	$ 45
220	$ 241,343	$ 43
221	$ 241,343	$ 42
222	$ 241,343	$ 40
223	$ 241,343	$ 38
224	$ 241,343	$ 37
225	$ 241,343	$ 35
226	$ 241,343	$ 34
227	$ 241,343	$ 33
228	$ 241,343	$ 32
229	$ 241,343	$ 30
230	$ 241,343	$ 29
231	$ 241,343	$ 28
232	$ 241,343	$ 27
233	$ 241,343	$ 26
234	$ 241,343	$ 25
235	$ 241,343	$ 24
236	$ 241,343	$ 23
237	$ 241,343	$ 22
238	$ 241,343	$ 21
239	$ 241,343	$ 20
240	$ 241,343	$ 20
241	$ 241,343	$ 19
242	$ 241,343	$ 18

BOE-C6-0060098

Appendix J
Table 1.1
Detailed Cost, Hydraulic Containment
Annual Operations and Maintenance - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
243	$ 241,343	$ 18
244	$ 241,343	$ 17
245	$ 241,343	$ 16
246	$ 241,343	$ 16
247	$ 241,343	$ 15
248	$ 241,343	$ 14
249	$ 241,343	$ 14
250	$ 241,343	$ 13
251	$ 241,343	$ 13
252	$ 241,343	$ 12
253	$ 241,343	$ 12
254	$ 241,343	$ 11
255	$ 241,343	$ 11
256	$ 241,343	$ 11
257	$ 241,343	$ 10
258	$ 241,343	$ 10
259	$ 241,343	$ 9.35
260	$ 241,343	$ 8.99
261	$ 241,343	$ 8.65
262	$ 241,343	$ 8.32
263	$ 241,343	$ 8.00
264	$ 241,343	$ 7.69
265	$ 241,343	$ 7.39
266	$ 241,343	$ 7.11
267	$ 241,343	$ 6.83
268	$ 241,343	$ 6.57
269	$ 241,343	$ 6.32
270	$ 241,343	$ 6.08
271	$ 241,343	$ 5.84
272	$ 241,343	$ 5.62
273	$ 241,343	$ 5.40
274	$ 241,343	$ 5.19
275	$ 241,343	$ 4.99
276	$ 241,343	$ 4.80
277	$ 241,343	$ 4.62
278	$ 241,343	$ 4.44
279	$ 241,343	$ 4.27
280	$ 241,343	$ 4.10
281	$ 241,343	$ 3.95
282	$ 241,343	$ 3.80
283	$ 241,343	$ 3.65
284	$ 241,343	$ 3.51
285	$ 241,343	$ 3.37
286	$ 241,343	$ 3.24
287	$ 241,343	$ 3.12
288	$ 241,343	$ 3.00
289	$ 241,343	$ 2.88
290	$ 241,343	$ 2.77

BOE-C6-0060099

Appendix J
Table 1.1
Detailed Cost, Hydraulic Containment
Annual Operations and Maintenance - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
291	$ 241,343	$ 2.67
292	$ 241,343	$ 2.56
293	$ 241,343	$ 2.47
294	$ 241,343	$ 2.37
295	$ 241,343	$ 2.28
296	$ 241,343	$ 2.19
297	$ 241,343	$ 2.11
298	$ 241,343	$ 2.03
299	$ 241,343	$ 1.95
300	$ 241,343	$ 1.87
301	$ 241,343	$ 1.80
302	$ 241,343	$ 1.73
303	$ 241,343	$ 1.67
304	$ 241,343	$ 1.60
305	$ 241,343	$ 1.54
306	$ 241,343	$ 1.48
307	$ 241,343	$ 1.42
308	$ 241,343	$ 1.37
309	$ 241,343	$ 1.32
310	$ 241,343	$ 1.27
311	$ 241,343	$ 1.22
312	$ 241,343	$ 1.17
313	$ 241,343	$ 1.13
314	$ 241,343	$ 1.08
315	$ 241,343	$ 1.04
316	$ 241,343	$ 1.00
317	$ 241,343	$ 0.96
318	$ 241,343	$ 0.92
319	$ 241,343	$ 0.89
320	$ 241,343	$ 0.85
321	$ 241,343	$ 0.82
322	$ 241,343	$ 0.79
323	$ 241,343	$ 0.76
324	$ 241,343	$ 0.73
325	$ 241,343	$ 0.70
326	$ 241,343	$ 0.68
327	$ 241,343	$ 0.65
328	$ 241,343	$ 0.62
329	$ 241,343	$ 0.60
330	$ 241,343	$ 0.58
331	$ 241,343	$ 0.56
332	$ 241,343	$ 0.53
333	$ 241,343	$ 0.51
334	$ 241,343	$ 0.49
335	$ 241,343	$ 0.47
336	$ 241,343	$ 0.46
337	$ 241,343	$ 0.44
338	$ 241,343	$ 0.42

Appendix J
Table 1.1
Detailed Cost, Hydraulic Containment
Annual Operations and Maintenance - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
339	$ 241,343	$ 0.41
340	$ 241,343	$ 0.39
341	$ 241,343	$ 0.38
342	$ 241,343	$ 0.36
343	$ 241,343	$ 0.35
344	$ 241,343	$ 0.33
345	$ 241,343	$ 0.32
346	$ 241,343	$ 0.31
347	$ 241,343	$ 0.30
348	$ 241,343	$ 0.29
349	$ 241,343	$ 0.27
350	$ 241,343	$ 0.26
351	$ 241,343	$ 0.25
352	$ 241,343	$ 0.24
353	$ 241,343	$ 0.23
354	$ 241,343	$ 0.23
355	$ 241,343	$ 0.22
356	$ 241,343	$ 0.21
357	$ 241,343	$ 0.20
358	$ 241,343	$ 0.19
359	$ 241,343	$ 0.19
360	$ 241,343	$ 0.18
361	$ 241,343	$ 0.17
362	$ 241,343	$ 0.16
363	$ 241,343	$ 0.16
364	$ 241,343	$ 0.15
365	$ 241,343	$ 0.15
366	$ 241,343	$ 0.14
367	$ 241,343	$ 0.14
368	$ 241,343	$ 0.13
369	$ 241,343	$ 0.13
370	$ 241,343	$ 0.12
371	$ 241,343	$ 0.12
372	$ 241,343	$ 0.11
373	$ 241,343	$ 0.11
374	$ 241,343	$ 0.10
375	$ 241,343	$ 0.10
376	$ 241,343	$ 0.10
377	$ 241,343	$ 0.09
378	$ 241,343	$ 0.09
379	$ 241,343	$ 0.08
380	$ 241,343	$ 0.08
381	$ 241,343	$ 0.08
382	$ 241,343	$ 0.08
383	$ 241,343	$ 0.07
384	$ 241,343	$ 0.07
385	$ 241,343	$ 0.07
386	$ 241,343	$ 0.06

Appendix J
Table 1.1
Detailed Cost, Hydraulic Containment
Annual Operations and Maintenance - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
387	$ 241,343	$ 0.06
388	$ 241,343	$ 0.06
389	$ 241,343	$ 0.06
390	$ 241,343	$ 0.05
391	$ 241,343	$ 0.05
392	$ 241,343	$ 0.05
393	$ 241,343	$ 0.05
394	$ 241,343	$ 0.05
395	$ 241,343	$ 0.05
396	$ 241,343	$ 0.04
397	$ 241,343	$ 0.04
398	$ 241,343	$ 0.04
399	$ 241,343	$ 0.04
400	$ 241,343	$ 0.04
401	$ 241,343	$ 0.04
402	$ 241,343	$ 0.03
403	$ 241,343	$ 0.03
404	$ 241,343	$ 0.03
405	$ 241,343	$ 0.03
406	$ 241,343	$ 0.03
407	$ 241,343	$ 0.03
408	$ 241,343	$ 0.03
409	$ 241,343	$ 0.03
410	$ 241,343	$ 0.03
411	$ 241,343	$ 0.02
412	$ 241,343	$ 0.02
413	$ 241,343	$ 0.02
414	$ 241,343	$ 0.02
415	$ 241,343	$ 0.02
416	$ 241,343	$ 0.02
417	$ 241,343	$ 0.02
418	$ 241,343	$ 0.02
419	$ 241,343	$ 0.02
420	$ 241,343	$ 0.02
421	$ 241,343	$ 0.02
422	$ 241,343	$ 0.02
423	$ 241,343	$ 0.02
424	$ 241,343	$ 0.01
425	$ 241,343	$ 0.01
426	$ 241,343	$ 0.01
427	$ 241,343	$ 0.01
428	$ 241,343	$ 0.01
429	$ 241,343	$ 0.01
430	$ 241,343	$ 0.01
431	$ 241,343	$ 0.01
432	$ 241,343	$ 0.01
433	$ 241,343	$ 0.01
434	$ 241,343	$ 0.01

Appendix J
Table 1.1
Detailed Cost, Hydraulic Containment
Annual Operations and Maintenance - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
435	$ 241,343	$ 0.01
436	$ 241,343	$ 0.01
437	$ 241,343	$ 0.01
438	$ 241,343	$ 0.01
439	$ 241,343	$ 0.01
440	$ 241,343	$ 0.01
441	$ 241,343	$ 0.01
442	$ 241,343	$ 0.01
443	$ 241,343	$ 0.01
444	$ 241,343	$ 0.01
445	$ 241,343	$ 0.01
446	$ 241,343	$ 0.01
447	$ 241,343	$ 0.01
448	$ 241,343	$ 0.01
449	$ 241,343	$ 0.01
450	$ 241,343	$ 0.01
451	$ 241,343	$ 0.01
452	$ 241,343	$ 0.005
453	$ 241,343	$ 0.005
454	$ 241,343	$ 0.004
455	$ 241,343	$ 0.004
456	$ 241,343	$ 0.004
457	$ 241,343	$ 0.004
458	$ 241,343	$ 0.004
459	$ 241,343	$ 0.004
460	$ 241,343	$ 0.004
461	$ 241,343	$ 0.003
462	$ 241,343	$ 0.003
463	$ 241,343	$ 0.003
464	$ 241,343	$ 0.003
465	$ 241,343	$ 0.003
466	$ 241,343	$ 0.003
467	$ 241,343	$ 0.003
468	$ 241,343	$ 0.003
469	$ 241,343	$ 0.002
470	$ 241,343	$ 0.002
471	$ 241,343	$ 0.002
472	$ 241,343	$ 0.002
473	$ 241,343	$ 0.002
474	$ 241,343	$ 0.002
475	$ 241,343	$ 0.002
476	$ 241,343	$ 0.002
477	$ 241,343	$ 0.002
478	$ 241,343	$ 0.002
479	$ 241,343	$ 0.002
480	$ 241,343	$ 0.002
481	$ 241,343	$ 0.002
482	$ 241,343	$ 0.001

Appendix J
Table 1.1
Detailed Cost, Hydraulic Containment
Annual Operations and Maintenance - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
483	$ 241,343	$ 0.001
484	$ 241,343	$ 0.001
485	$ 241,343	$ 0.001
486	$ 241,343	$ 0.001
487	$ 241,343	$ 0.001
488	$ 241,343	$ 0.001
489	$ 241,343	$ 0.001
490	$ 241,343	$ 0.001
491	$ 241,343	$ 0.001
492	$ 241,343	$ 0.001
493	$ 241,343	$ 0.001
494	$ 241,343	$ 0.001
495	$ 241,343	$ 0.001
496	$ 241,343	$ 0.001
497	$ 241,343	$ 0.001
498	$ 241,343	$ 0.001
499	$ 241,343	$ 0.001
500	$ 241,343	$ 0.001
501	$ 241,343	$ 0.001
502	$ 241,343	$ 0.001
503	$ 241,343	$ 0.001
504	$ 241,343	$ 0.001
505	$ 241,343	$ 0.001
506	$ 241,343	$ 0.001
507	$ 241,343	$ 0.001
508	$ 241,343	$ 0.001
509 [2]	$ 241,343	$ 0.001
3620	$ 241,343	$ 0.000
Totals	**$ 861,593,285**	**$ 848,999**

Notes:

[1] Annual O&M cost of $241,343 is calculated on Table J-1.2

[2] The NPV costs for years between 509 and 3620 are less than $0.001 each year and do not effect the total NPV cost to the nearest $1, though the total undiscounted cost is calculated based on $241,343 annually from years 51 to 3620.

Appendix J
Table 1.2
Detailed Cost, Hydraulic Containment
Annual Operations and Maintenance

Item	Consultant Labor (Operations and Reporting)	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	100	$ 150	/Hour	$ 15,000	
2	Senior Engineer/Geologist	0	$ 125	/Hour	$ -	
3	Mid-Level Engineer/Geologist	248	$ 100	/Hour	$ 24,800	
4	Junior/Field Engineer/Geologist	0	$ 75	/Hour	$ -	
5	Field Technician	672	$ 75	/Hour	$ 50,400	
6	Clerical/Drafting	104	$ 50	/Hour	$ 5,200	
	Consultant Labor Cost for Operations				**$ 95,400**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Waste Management**					
a	Filtration Generated Waste T&D (Listed Waste for Incineration)	12	$ 400.00	/drum	$ 4,800	1
b	6000-lb LGAC Change-Outs	6	$ 12,000	/Change-Out	$ 72,000	
	Total Waste Management				**$ 76,800**	
8	**Lab Analytical**					
a	Water Analysis - VOCs (EPA Method 8260B)	104	$ 100	/Each	$ 10,400	2
	Total Lab Analytical				**$ 10,400**	
9	**Miscellaneous**					
a	Portable Toilet Rental	12	$ 100	/Month	$ 1,200	3
b	Extraction Pump Maintenance Parts	12	$ 1,000	/Month	$ 12,000	
c	Operator Truck Usage (One Truck per Operator)	104	$ 100	/Day/Truck	$ 10,400	
	Total Miscellaneous				**$ 23,600**	
	Total Subcontractor Cost				**$ 110,800**	

Appendix J
Table 1.2
Detailed Cost, Hydraulic Containment
Annual Operations and Maintenance

Item	Utilities	Quantity	Unit Cost		Cost	Cost Ref.
10	**Electricity Usage**					
a	Groundwater Extraction and Transfer Pumps	230,265	$ 0.1045	/kWh	$ 24,063	4
	Total Utilities				**$ 24,063**	

CONSULTANT LABOR COST	**$ 95,400**	
SUBCONTRACTOR COST w/10% MARKUP	**$ 121,880**	
UTILITIES COST (NO MARKUP)	**$ 24,063**	
TOTAL OPERATIONS AND MAINTENANCE COST	**$ 241,343**	

Cost Source Reference

1 Clean Harbors Quote Dated October 10, 2007
2 Verbal Quote from Test America
3 Verbal Quote from A-1 Coast Port-A-Toilet
4 Shedule A-3 LADWP Rate (Second Quarter 2008)

BOE-C6-0060106

Appendix J
Table 1.3
Detailed Cost, Hydraulic Containment
Well Rehabilitation - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
51	$ 45,645	$ 6,176
53	$ 45,645	$ 5,710
55	$ 45,645	$ 5,279
57	$ 45,645	$ 4,881
59	$ 45,645	$ 4,513
61	$ 45,645	$ 4,172
63	$ 45,645	$ 3,857
65	$ 45,645	$ 3,566
67	$ 45,645	$ 3,297
69	$ 45,645	$ 3,049
71	$ 45,645	$ 2,819
73	$ 45,645	$ 2,606
75	$ 45,645	$ 2,409
77	$ 45,645	$ 2,228
79	$ 45,645	$ 2,059
81	$ 45,645	$ 1,904
83	$ 45,645	$ 1,760
85	$ 45,645	$ 1,628
87	$ 45,645	$ 1,505
89	$ 45,645	$ 1,391
91	$ 45,645	$ 1,286
93	$ 45,645	$ 1,189
95	$ 45,645	$ 1,100
97	$ 45,645	$ 1,017
99	$ 45,645	$ 940
101	$ 45,645	$ 869
103	$ 45,645	$ 803
105	$ 45,645	$ 743
107	$ 45,645	$ 687
109	$ 45,645	$ 635
111	$ 45,645	$ 587
113	$ 45,645	$ 543
115	$ 45,645	$ 502
117	$ 45,645	$ 464
119	$ 45,645	$ 429
121	$ 45,645	$ 397
123	$ 45,645	$ 367
125	$ 45,645	$ 339
127	$ 45,645	$ 313
129	$ 45,645	$ 290
131	$ 45,645	$ 268

Appendix J
Table 1.3
Detailed Cost, Hydraulic Containment
Well Rehabilitation - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
133	$ 45,645	$ 248
135	$ 45,645	$ 229
137	$ 45,645	$ 212
139	$ 45,645	$ 196
141	$ 45,645	$ 181
143	$ 45,645	$ 167
145	$ 45,645	$ 155
147	$ 45,645	$ 143
149	$ 45,645	$ 132
151	$ 45,645	$ 122
153	$ 45,645	$ 113
155	$ 45,645	$ 105
157	$ 45,645	$ 97
159	$ 45,645	$ 89
161	$ 45,645	$ 83
163	$ 45,645	$ 76
165	$ 45,645	$ 71
167	$ 45,645	$ 65
169	$ 45,645	$ 60
171	$ 45,645	$ 56
173	$ 45,645	$ 52
175	$ 45,645	$ 48
177	$ 45,645	$ 44
179	$ 45,645	$ 41
181	$ 45,645	$ 38
183	$ 45,645	$ 35
185	$ 45,645	$ 32
187	$ 45,645	$ 30
189	$ 45,645	$ 28
191	$ 45,645	$ 25
193	$ 45,645	$ 24
195	$ 45,645	$ 22
197	$ 45,645	$ 20
199	$ 45,645	$ 19
201	$ 45,645	$ 17
203	$ 45,645	$ 16
205	$ 45,645	$ 15
207	$ 45,645	$ 14
209	$ 45,645	$ 13
211	$ 45,645	$ 12
213	$ 45,645	$ 11

Appendix J
Table 1.3
Detailed Cost, Hydraulic Containment
Well Rehabilitation - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
215	$ 45,645	$ 10
217	$ 45,645	$ 9.19
219	$ 45,645	$ 8.49
221	$ 45,645	$ 7.85
223	$ 45,645	$ 7.26
225	$ 45,645	$ 6.71
227	$ 45,645	$ 6.21
229	$ 45,645	$ 5.74
231	$ 45,645	$ 5.31
233	$ 45,645	$ 4.90
235	$ 45,645	$ 4.53
237	$ 45,645	$ 4.19
239	$ 45,645	$ 3.88
241	$ 45,645	$ 3.58
243	$ 45,645	$ 3.31
245	$ 45,645	$ 3.06
247	$ 45,645	$ 2.83
249	$ 45,645	$ 2.62
251	$ 45,645	$ 2.42
253	$ 45,645	$ 2.24
255	$ 45,645	$ 2.07
257	$ 45,645	$ 1.91
259	$ 45,645	$ 1.77
261	$ 45,645	$ 1.64
263	$ 45,645	$ 1.51
265	$ 45,645	$ 1.40
267	$ 45,645	$ 1.29
269	$ 45,645	$ 1.20
271	$ 45,645	$ 1.10
273	$ 45,645	$ 1.02
275	$ 45,645	$ 0.94
277	$ 45,645	$ 0.87
279	$ 45,645	$ 0.81
281	$ 45,645	$ 0.75
283	$ 45,645	$ 0.69
285	$ 45,645	$ 0.64
287	$ 45,645	$ 0.59
289	$ 45,645	$ 0.55
291	$ 45,645	$ 0.50
293	$ 45,645	$ 0.47
295	$ 45,645	$ 0.43

Appendix J
Table 1.3
Detailed Cost, Hydraulic Containment
Well Rehabilitation - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
297	$ 45,645	$ 0.40
299	$ 45,645	$ 0.37
301	$ 45,645	$ 0.34
303	$ 45,645	$ 0.31
305	$ 45,645	$ 0.29
307	$ 45,645	$ 0.27
309	$ 45,645	$ 0.25
311	$ 45,645	$ 0.23
313	$ 45,645	$ 0.21
315	$ 45,645	$ 0.20
317	$ 45,645	$ 0.18
319	$ 45,645	$ 0.17
321	$ 45,645	$ 0.16
323	$ 45,645	$ 0.14
325	$ 45,645	$ 0.13
327	$ 45,645	$ 0.12
329	$ 45,645	$ 0.11
331	$ 45,645	$ 0.11
333	$ 45,645	$ 0.10
335	$ 45,645	$ 0.09
337	$ 45,645	$ 0.08
339	$ 45,645	$ 0.08
341	$ 45,645	$ 0.07
343	$ 45,645	$ 0.07
345	$ 45,645	$ 0.06
347	$ 45,645	$ 0.06
349	$ 45,645	$ 0.05
351	$ 45,645	$ 0.05
353	$ 45,645	$ 0.04
355	$ 45,645	$ 0.04
357	$ 45,645	$ 0.04
359	$ 45,645	$ 0.04
361	$ 45,645	$ 0.03
363	$ 45,645	$ 0.03
365	$ 45,645	$ 0.03
367	$ 45,645	$ 0.03
369	$ 45,645	$ 0.02
371	$ 45,645	$ 0.02
373	$ 45,645	$ 0.02
375	$ 45,645	$ 0.02
377	$ 45,645	$ 0.02

Appendix J
Table 1.3
Detailed Cost, Hydraulic Containment
Well Rehabilitation - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
379	$ 45,645	$ 0.02
381	$ 45,645	$ 0.01
383	$ 45,645	$ 0.01
385	$ 45,645	$ 0.01
387	$ 45,645	$ 0.01
389	$ 45,645	$ 0.01
391	$ 45,645	$ 0.01
393	$ 45,645	$ 0.01
395	$ 45,645	$ 0.01
397	$ 45,645	$ 0.01
399	$ 45,645	$ 0.01
401	$ 45,645	$ 0.01
403	$ 45,645	$ 0.01
405	$ 45,645	$ 0.01
407	$ 45,645	$ 0.01
409	$ 45,645	$ 0.005
411	$ 45,645	$ 0.005
413	$ 45,645	$ 0.004
415	$ 45,645	$ 0.004
417	$ 45,645	$ 0.004
419	$ 45,645	$ 0.003
421	$ 45,645	$ 0.003
423	$ 45,645	$ 0.003
425	$ 45,645	$ 0.003
427	$ 45,645	$ 0.002
429	$ 45,645	$ 0.002
431	$ 45,645	$ 0.002
433	$ 45,645	$ 0.002
435	$ 45,645	$ 0.002
437	$ 45,645	$ 0.002
439	$ 45,645	$ 0.002
441	$ 45,645	$ 0.001
443	$ 45,645	$ 0.001
445	$ 45,645	$ 0.001
447	$ 45,645	$ 0.001
449	$ 45,645	$ 0.001
451	$ 45,645	$ 0.001
453	$ 45,645	$ 0.001
455	$ 45,645	$ 0.001
457	$ 45,645	$ 0.001
459	$ 45,645	$ 0.001

Appendix J
Table 1.3
Detailed Cost, Hydraulic Containment
Well Rehabilitation - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
461	$ 45,645	$ 0.001
463	$ 45,645	$ 0.001
465	$ 45,645	$ 0.001
467 [2]	$ 45,645	$ 0.001
3619	$ 45,645	$ 0.000
Totals	**$81,476,325**	**$ 81,860**

Notes:

[1] Well rehabilitation cost of $45,645 for each year shown is calculated on Table J-1.4

[2] The NPV costs for years between 467 and 3619 are less than $0.001 each year and do not effect the total NPV cost to the nearest $1, though the total undiscounted cost is calculated based on $45,645 once every two years from years 51 to 3619.

Appendix J
Table 1.4
Detailed Cost, Hydraulic Containment
Well Rehabilitation Once Every 2 Years

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	8	$ 150	/Hour	$ 1,200	
2	Senior Engineer/Geologist	0	$ 125	/Hour	$ -	
3	Mid-Level Engineer/Geologist	20	$ 100	/Hour	$ 2,000	
4	Junior/Field Engineer/Geologist	112	$ 75	/Hour	$ 8,400	
5	Field Technician	0	$ 75	/Hour	$ -	
6	Clerical/Drafting	0	$ 50	/Hour	$ -	
	Total Consultant Labor Cost				**$ 11,600**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Develop Extraction and Injection Wells**					
a	Development Rig	1	$ 2,000	/Day	$ 2,000	1
b	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
c	Other Direct Costs	1	$ 400	/Day	$ 400	
	Cost per Well				$ 2,900	
	Number of Wells (1 Well Developed per Day)				9	
	Subtotal - Develop Extraction and Injection Wells				**$ 26,100**	
8	**Waste Management**					
a	Waste Tank Rental	30	$ 40	/Day	$ 1,200	2
b	Waste Tank Rental Delivery - Mob and Demob	1	$ 900	/Each	$ 900	2
	Vacuum Truck	3	$ 750	/day	$ 2,250	
	Waste Characterization/Profiling	1	$ 500	/Each	$ 500	
	Subtotal - Waste Management				**$ 4,850**	
	Total Subcontractor Cost w/10% Markup				**$ 34,045**	

	TOTAL WELL REHABILITATION COST	**$ 45,645**

Cost Source Reference

1 Verbal Quote from Cascade Drilling

2 Verbal Quote from NRC Environmental

Appendix J
Table 1.5
Detailed Cost, Hydraulic Containment
Well Pump and Controls Replacement - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
51	$ 33,460	$ 4,527
53	$ 33,460	$ 4,186
55	$ 33,460	$ 3,870
57	$ 33,460	$ 3,578
59	$ 33,460	$ 3,308
61	$ 33,460	$ 3,058
63	$ 33,460	$ 2,828
65	$ 33,460	$ 2,614
67	$ 33,460	$ 2,417
69	$ 33,460	$ 2,235
71	$ 33,460	$ 2,066
73	$ 33,460	$ 1,910
75	$ 33,460	$ 1,766
77	$ 33,460	$ 1,633
79	$ 33,460	$ 1,510
81	$ 33,460	$ 1,396
83	$ 33,460	$ 1,291
85	$ 33,460	$ 1,193
87	$ 33,460	$ 1,103
89	$ 33,460	$ 1,020
91	$ 33,460	$ 943
93	$ 33,460	$ 872
95	$ 33,460	$ 806
97	$ 33,460	$ 745
99	$ 33,460	$ 689
101	$ 33,460	$ 637
103	$ 33,460	$ 589
105	$ 33,460	$ 545
107	$ 33,460	$ 503
109	$ 33,460	$ 465
111	$ 33,460	$ 430
113	$ 33,460	$ 398
115	$ 33,460	$ 368
117	$ 33,460	$ 340
119	$ 33,460	$ 314
121	$ 33,460	$ 291
123	$ 33,460	$ 269
125	$ 33,460	$ 249
127	$ 33,460	$ 230
129	$ 33,460	$ 212
131	$ 33,460	$ 196
133	$ 33,460	$ 182
135	$ 33,460	$ 168
137	$ 33,460	$ 155
139	$ 33,460	$ 144
141	$ 33,460	$ 133

Appendix J
Table 1.5
Detailed Cost, Hydraulic Containment
Well Pump and Controls Replacement - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
143	$ 33,460	$ 123
145	$ 33,460	$ 113
147	$ 33,460	$ 105
149	$ 33,460	$ 97
151	$ 33,460	$ 90
153	$ 33,460	$ 83
155	$ 33,460	$ 77
157	$ 33,460	$ 71
159	$ 33,460	$ 65
161	$ 33,460	$ 61
163	$ 33,460	$ 56
165	$ 33,460	$ 52
167	$ 33,460	$ 48
169	$ 33,460	$ 44
171	$ 33,460	$ 41
173	$ 33,460	$ 38
175	$ 33,460	$ 35
177	$ 33,460	$ 32
179	$ 33,460	$ 30
181	$ 33,460	$ 28
183	$ 33,460	$ 26
185	$ 33,460	$ 24
187	$ 33,460	$ 22
189	$ 33,460	$ 20
191	$ 33,460	$ 19
193	$ 33,460	$ 17
195	$ 33,460	$ 16
197	$ 33,460	$ 15
199	$ 33,460	$ 14
201	$ 33,460	$ 13
203	$ 33,460	$ 12
205	$ 33,460	$ 11
207	$ 33,460	$ 10
209	$ 33,460	$ 9.22
211	$ 33,460	$ 8.52
213	$ 33,460	$ 7.88
215	$ 33,460	$ 7.28
217	$ 33,460	$ 6.73
219	$ 33,460	$ 6.23
221	$ 33,460	$ 5.76
223	$ 33,460	$ 5.32
225	$ 33,460	$ 4.92
227	$ 33,460	$ 4.55
229	$ 33,460	$ 4.21
231	$ 33,460	$ 3.89
233	$ 33,460	$ 3.60

BOE-C6-0060115

Appendix J
Table 1.5
Detailed Cost, Hydraulic Containment
Well Pump and Controls Replacement - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
235	$ 33,460	$ 3.32
237	$ 33,460	$ 3.07
239	$ 33,460	$ 2.84
241	$ 33,460	$ 2.63
243	$ 33,460	$ 2.43
245	$ 33,460	$ 2.25
247	$ 33,460	$ 2.08
249	$ 33,460	$ 1.92
251	$ 33,460	$ 1.77
253	$ 33,460	$ 1.64
255	$ 33,460	$ 1.52
257	$ 33,460	$ 1.40
259	$ 33,460	$ 1.30
261	$ 33,460	$ 1.20
263	$ 33,460	$ 1.11
265	$ 33,460	$ 1.02
267	$ 33,460	$ 0.95
269	$ 33,460	$ 0.88
271	$ 33,460	$ 0.81
273	$ 33,460	$ 0.75
275	$ 33,460	$ 0.69
277	$ 33,460	$ 0.64
279	$ 33,460	$ 0.59
281	$ 33,460	$ 0.55
283	$ 33,460	$ 0.51
285	$ 33,460	$ 0.47
287	$ 33,460	$ 0.43
289	$ 33,460	$ 0.40
291	$ 33,460	$ 0.37
293	$ 33,460	$ 0.34
295	$ 33,460	$ 0.32
297	$ 33,460	$ 0.29
299	$ 33,460	$ 0.27
301	$ 33,460	$ 0.25
303	$ 33,460	$ 0.23
305	$ 33,460	$ 0.21
307	$ 33,460	$ 0.20
309	$ 33,460	$ 0.18
311	$ 33,460	$ 0.17
313	$ 33,460	$ 0.16
315	$ 33,460	$ 0.14
317	$ 33,460	$ 0.13
319	$ 33,460	$ 0.12
321	$ 33,460	$ 0.11
323	$ 33,460	$ 0.11
325	$ 33,460	$ 0.10

Appendix J
Table 1.5
Detailed Cost, Hydraulic Containment
Well Pump and Controls Replacement - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
327	$ 33,460	$ 0.09
329	$ 33,460	$ 0.08
331	$ 33,460	$ 0.08
333	$ 33,460	$ 0.07
335	$ 33,460	$ 0.07
337	$ 33,460	$ 0.06
339	$ 33,460	$ 0.06
341	$ 33,460	$ 0.05
343	$ 33,460	$ 0.05
345	$ 33,460	$ 0.04
347	$ 33,460	$ 0.04
349	$ 33,460	$ 0.04
351	$ 33,460	$ 0.04
353	$ 33,460	$ 0.03
355	$ 33,460	$ 0.03
357	$ 33,460	$ 0.03
359	$ 33,460	$ 0.03
361	$ 33,460	$ 0.02
363	$ 33,460	$ 0.02
365	$ 33,460	$ 0.02
367	$ 33,460	$ 0.02
369	$ 33,460	$ 0.02
371	$ 33,460	$ 0.02
373	$ 33,460	$ 0.01
375	$ 33,460	$ 0.01
377	$ 33,460	$ 0.01
379	$ 33,460	$ 0.01
381	$ 33,460	$ 0.01
383	$ 33,460	$ 0.01
385	$ 33,460	$ 0.01
387	$ 33,460	$ 0.01
389	$ 33,460	$ 0.01
391	$ 33,460	$ 0.01
393	$ 33,460	$ 0.01
395	$ 33,460	$ 0.01
397	$ 33,460	$ 0.01
399	$ 33,460	$ 0.01
401	$ 33,460	$ 0.005
403	$ 33,460	$ 0.005
405	$ 33,460	$ 0.004
407	$ 33,460	$ 0.004
409	$ 33,460	$ 0.004
411	$ 33,460	$ 0.003
413	$ 33,460	$ 0.003
415	$ 33,460	$ 0.003
417	$ 33,460	$ 0.003

Appendix J
Table 1.5
Detailed Cost, Hydraulic Containment
Well Pump and Controls Replacement - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
419	$ 33,460	$ 0.002
421	$ 33,460	$ 0.002
423	$ 33,460	$ 0.002
425	$ 33,460	$ 0.002
427	$ 33,460	$ 0.002
429	$ 33,460	$ 0.002
431	$ 33,460	$ 0.002
433	$ 33,460	$ 0.001
435	$ 33,460	$ 0.001
437	$ 33,460	$ 0.001
439	$ 33,460	$ 0.001
441	$ 33,460	$ 0.001
443	$ 33,460	$ 0.001
445	$ 33,460	$ 0.001
447	$ 33,460	$ 0.001
449	$ 33,460	$ 0.001
451	$ 33,460	$ 0.001
453	$ 33,460	$ 0.001
455	$ 33,460	$ 0.001
457	$ 33,460	$ 0.001
459 [2]	$ 33,460	$ 0.001
3619	$ 33,460	$ 0.000
Totals	**$ 59,726,100**	**$ 60,007**

Notes:

[1] Well equipment replacement cost of $33,460 for each year shown is calculated on Table J-1.6

[2] The NPV costs for years between 459 and 3619 are less than $0.001 each year and do not effect the total NPV cost to the nearest $1, though the total undiscounted cost is calculated based on $33,460 once every two years from years 51 to 3619.

BOE-C6-0060118

Appendix J
Table 1.6
Detailed Cost, Hydraulic Containment
Well Pump and Controls Replacement Once Every 2 Years

Item	Consultant Labor and Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
1	**Field Technician (Consultant Labor - Not Subject to Markup)**	56	$ 75	Hour	$ 4,200	
2	**Well Equipment**					
a	Replacement Groundwater Extraction Pump	7	$ 3,000	Each	$ 21,000	
b	Replacement Wellhead Controls (Wireline Rig)	7	$ 800		$ 5,600	
	Total Extraction Well Equipment				$ 26,600	
	CONSULTANT LABOR COST				$ 4,200	
	DIRECT COSTS w/10% MARKUP				$ 29,260	
	TOTAL WELL PUMP AND CONTROL REPLACEMENT				$ 33,460	

Appendix J
Table 1.7
Detailed Cost, Hydraulic Containment
Well Assembly Replacement - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
51	$ 17,286	$ 2,339
56	$ 17,286	$ 1,922
61	$ 17,286	$ 1,580
66	$ 17,286	$ 1,299
71	$ 17,286	$ 1,067
76	$ 17,286	$ 877
81	$ 17,286	$ 721
86	$ 17,286	$ 593
91	$ 17,286	$ 487
96	$ 17,286	$ 400
101	$ 17,286	$ 329
106	$ 17,286	$ 270
111	$ 17,286	$ 222
116	$ 17,286	$ 183
121	$ 17,286	$ 150
126	$ 17,286	$ 123
131	$ 17,286	$ 101
136	$ 17,286	$ 83
141	$ 17,286	$ 69
146	$ 17,286	$ 56
151	$ 17,286	$ 46
156	$ 17,286	$ 38
161	$ 17,286	$ 31
166	$ 17,286	$ 26
171	$ 17,286	$ 21
176	$ 17,286	$ 17
181	$ 17,286	$ 14
186	$ 17,286	$ 12
191	$ 17,286	$ 10
196	$ 17,286	$ 7.93
201	$ 17,286	$ 6.52
206	$ 17,286	$ 5.36
211	$ 17,286	$ 4.40
216	$ 17,286	$ 3.62
221	$ 17,286	$ 2.97
226	$ 17,286	$ 2.44
231	$ 17,286	$ 2.01
236	$ 17,286	$ 1.65
241	$ 17,286	$ 1.36
246	$ 17,286	$ 1.12
251	$ 17,286	$ 0.92
256	$ 17,286	$ 0.75
261	$ 17,286	$ 0.62
266	$ 17,286	$ 0.51
271	$ 17,286	$ 0.42
276	$ 17,286	$ 0.34
281	$ 17,286	$ 0.28
286	$ 17,286	$ 0.23
291	$ 17,286	$ 0.19
296	$ 17,286	$ 0.16

BOE-C6-0060120

Appendix J
Table 1.7
Detailed Cost, Hydraulic Containment
Well Assembly Replacement - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
301	$ 17,286	$ 0.13
306	$ 17,286	$ 0.11
311	$ 17,286	$ 0.09
316	$ 17,286	$ 0.07
321	$ 17,286	$ 0.06
326	$ 17,286	$ 0.05
331	$ 17,286	$ 0.04
336	$ 17,286	$ 0.03
341	$ 17,286	$ 0.03
346	$ 17,286	$ 0.02
351	$ 17,286	$ 0.02
356	$ 17,286	$ 0.01
361	$ 17,286	$ 0.01
366	$ 17,286	$ 0.01
371	$ 17,286	$ 0.01
376	$ 17,286	$ 0.01
381	$ 17,286	$ 0.01
386	$ 17,286	$ 0.005
391	$ 17,286	$ 0.004
396	$ 17,286	$ 0.003
401	$ 17,286	$ 0.003
406	$ 17,286	$ 0.002
411	$ 17,286	$ 0.002
416	$ 17,286	$ 0.001
421	$ 17,286	$ 0.001
426	$ 17,286	$ 0.001
431	$ 17,286	$ 0.001
436	$ 17,286	$ 0.001
441 [2]	$ 17,286	$ 0.001
3616	$ 17,286	$ 0.000
Totals	**$ 12,341,847**	**$ 13,134**

Notes:

[1] Well equipment replacement cost of $17,286 for each year shown is calculated on Table J-1.8

[2] The NPV costs for years between 441 and 3616 are less than $0.001 each year and do not effect the total NPV cost to the nearest $1, though the total undiscounted cost is calculated based on $17,286 once every five years from years 51 to 3616.

Appendix J
Table 1.8
Detailed Cost, Hydraulic Containment
Well Assembly Replacement Once Every 5 Years

Item	Consultant Labor and Direct Costs	Quantity	Unit Cost			Cost		Cost Ref.
1	**Field Technician (Consultant Labor - Not Subject to Markup)**	72	$	75	Hour	$	5,400	
2	**Extraction Well Assemblies**							
a	Well Head Assemblies	7	$	500	Each	$	3,500	
b	Static Pressure Gage	7	$	50	/Each	$	350	1
c	Temperature Indicator	7	$	130	/Each	$	910	1
d	Flow Sensor	7	$	250	/Each	$	1,750	2
e	Differential Pressure Gage	7	$	315	/Each	$	2,205	2
	Total Extraction Well Assemblies					$	8,715	
3	**Injection Well Assemblies**							
a	Well Head Assemblies	2	$	300	Each	$	600	
b	Static Pressure Gage	2	$	50	/Each	$	100	1
c	Temperature Indicator	2	$	130	/Each	$	260	1
d	Flow Sensor	2	$	250	/Each	$	500	2
e	Differential Pressure Gage	2	$	315	/Each	$	630	2
	Total Injection Well Assemblies					$	2,090	
	CONSULTANT LABOR COST					$	5,400	
	DIRECT COSTS w/10% MARKUP					$	11,886	
	TOTAL WELL FIELD EQUIPMENT INSTALLTION COST					$	17,286	

Cost Source Reference

1 Grainger Catalog Price
2 Dwyer Instruments, Inc. Catalog Price

Appendix J
Table 1.9
Detailed Cost, Hydraulic Containment
Treatment Equipment Replacement - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
71	$ 106,795	$ 6,595
91	$ 106,795	$ 3,010
111	$ 106,795	$ 1,374
131	$ 106,795	$ 627
151	$ 106,795	$ 286
171	$ 106,795	$ 131
191	$ 106,795	$ 60
211	$ 106,795	$ 27
231	$ 106,795	$ 12
251	$ 106,795	$ 5.66
271	$ 106,795	$ 2.59
291	$ 106,795	$ 1.18
311	$ 106,795	$ 0.54
331	$ 106,795	$ 0.25
351	$ 106,795	$ 0.11
371	$ 106,795	$ 0.05
391	$ 106,795	$ 0.02
411	$ 106,795	$ 0.01
431	$ 106,795	$ 0.00
451	$ 106,795	$ 0.002
471 [2]	$ 106,795	$ 0.001
3631	$ 106,795	$ 0.000
Totals	**$ 19,116,233**	**$12,131**

Notes:
[1] Treatment equipment replacement cost of $106,795 for each year shown is calculated on Table J-1.10

[2] The NPV costs for years between 471 and 3631 are less than $0.001 each year and do not effect the total NPV cost to the nearest $1, though the total undiscounted cost is calculated based on $106,795 once every twenty years from years 71 to 3631.

Appendix J
Table 1.10
Detailed Cost, Hydraulic Containment
Treatment Equipment Replacement Once Every 20 Years

Item	Direct Costs	Quantity	Unit Cost			Cost	Cost Ref.
1	6000-lb LGAC Vessel	3	$	25,000	/Each	$ 75,000	
2	Dual Filter Bag System	1	$	13,000	/Each	$ 13,000	1
3	Transfer Pump (100 gpm)	2	$	1,348	/Each	$ 2,696	
4	Transfer Pump (60 gpm)	2	$	536	/Each	$ 1,071	2
5	Transfer Pump (200 gpm)	3	$	1,773	/Each	$ 5,319	2
	TOTAL TREATMENT EQUIPMENT REPLACEMENT COST w/10% MARKUP					**$ 106,795**	

Cost Source Reference

1 Verbal Quote from BakerCorp
2 Grainger Catalog Price

Appendix J
Table 1.11
Detailed Cost, Hydraulic Containment
Well Replacement - NPV Analysis

Discount Rate 4%

Year	Cost[1] (Undiscounted)	Cost (NPV)
71	$ 762,221	$ 47,067
91	$ 762,221	$ 21,481
111	$ 762,221	$ 9,803
131	$ 762,221	$ 4,474
151	$ 762,221	$ 2,042
171	$ 762,221	$ 932
191	$ 762,221	$ 425
211	$ 762,221	$ 194
231	$ 762,221	$ 89
251	$ 762,221	$ 40
271	$ 762,221	$ 18
291	$ 762,221	$ 8.42
311	$ 762,221	$ 3.84
331	$ 762,221	$ 1.75
351	$ 762,221	$ 0.80
371	$ 762,221	$ 0.37
391	$ 762,221	$ 0.17
411	$ 762,221	$ 0.08
431	$ 762,221	$ 0.03
451	$ 762,221	$ 0.02
471	$ 762,221	$ 0.01
491	$ 762,221	$ 0.00
511	$ 762,221	$ 0.002
531 [2]	$ 762,221	$ 0.001
3631	$ 762,221	$ 0.000
Totals	**$ 136,437,513**	**$ 86,581**

Notes:

[1] Well replacement cost of $762,221 for each year shown is calculated on Table J-1.12

[2] The NPV costs for years between 531 and 3631 are less than $0.001 each year and do not effect the total NPV cost to the nearest $1, though the total undiscounted cost is calculated based on $762,221 once every twenty years

Appendix J
Table 1.12
Detailed Cost, Hydraulic Containment
Well Replacement Every 20 Years

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	65	$ 150	/Hour	$ 9,750	
2	Senior Engineer/Geologist	65	$ 125	/Hour	$ 8,125	
3	Mid-Level Engineer/Geologist	210	$ 100	/Hour	$ 21,000	
4	Junior/Field Engineer/Geologist	324	$ 75	/Hour	$ 24,300	
5	Field Technician	112	$ 75	/Hour	$ 8,400	
6	Clerical/Drafting	65	$ 50	/Hour	$ 3,250	
	Total Consultant Labor Cost				**$ 74,825**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**UBA Wells (Extraction Only)**					
a	Install Well using HSA Drilling	1	$ 12,000	/Each	$ 12,000	1
b	Forklift and Hopper Rental for Waste Handling	1	$ 250	/Day	$ 250	1
c	Drill Crew per Diem	1	$ 450	/Night	$ 450	1
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
f	Installation Permit	1	$ 201	/Each	$ 201	
g	Other Direct Costs	1	$ 300	/Day	$ 300	
	Cost per Well				$ 13,801	
	Number of Wells (1 Well Installed per Day)				3	
	Subtotal - UBA Wells				**$ 41,403**	
8	**Mobilization/Demobilization of Mud Rotary Drill Rig**	1	$ 12,000	/Each	**$ 12,000**	
9	**BFS Wells (Extraction Only)**					
a	Move Between Well Locations	1	$ 2,000	/Each	$ 2,000	2
b	Install Conductor Casing	1	$ 24,200	/Each	$ 24,200	2
c	Mud Change-Out and Pit Decon	1	$ 2,000	/Each	$ 2,000	2
d	Boring Under Conductor	1	$ 680	/Each	$ 680	2
e	Install Blank Casing	1	$ 10,000	/Each	$ 10,000	2
f	Install Screen with Sump	1	$ 1,400	/Each	$ 1,400	2
g	Packing Material	1	$ 4,000	/Each	$ 4,000	2
h	Forklift and Hopper Rental for Waste Handling	3	$ 400	/Day	$ 1,200	2
i	Standby for Cement Curing	6	$ 550	/Hour	$ 3,300	2
j	Vehicle Usage	3	$ 100	/Day	$ 300	
k	Equipment Rental and Supplies	3	$ 500	/Day	$ 1,500	
l	Other Direct Costs	3	$ 300	/Day	$ 900	
	Cost per Well				$ 51,480	
	Number of Wells (3 Days per Well for Installation)				4	
	Subtotal - BFS Wells				**$ 205,920**	
10	**Gage Wells (One Extraction, Two Injection)**					
a	Move Between Well Locations	1	$ 2,000	/Each	$ 2,000	2
b	Install Conductor Casing	1	$ 48,400	/Each	$ 48,400	2
c	Mud Change-Out and Pit Decon	1	$ 2,000	/Each	$ 2,000	2
d	Boring Under Conductor	1	$ 1,360	/Each	$ 1,360	2
e	Install Blank Casing	1	$ 20,000	/Each	$ 20,000	2
f	Install Screen with Sump	1	$ 2,800	/Each	$ 2,800	2
g	Packing Material	1	$ 8,000	/Each	$ 8,000	2
h	Forklift and Hopper Rental for Waste Handling	4	$ 400	/Day	$ 1,600	2
i	Standby for Cement Curing	8	$ 550	/Hour	$ 4,400	2
j	Vehicle Usage	4	$ 100	/Day	$ 400	
k	Equipment Rental and Supplies	4	$ 500	/Day	$ 2,000	
l	Other Direct Costs	4	$ 300	/Day	$ 1,200	
	Cost per Well				$ 94,160	
	Number of Wells (4 Days per Well for Installation)				3	
	Subtotal - Gage Wells				**$ 282,480**	

Appendix J
Table 1.12
Detailed Cost, Hydraulic Containment
Well Replacement Every 20 Years

Item		Subcontractor Cost	Quantity	Unit Cost			Cost		Cost Ref.
11		**Waste Management**							
	a	Waste Tank Rental	60	$	40	/Day	$	2,400	3
	b	Waste Tank Rental Delivery - Mob and Demob	2	$	900	/Each	$	1,800	3
	c	Waste Bin Rental	180	$	15	/Day	$	2,700	3
	d	Waste Bin Rental Delivery - Mob and Demob	6	$	500	/Each	$	3,000	3
	e	Transport of Hazardous Soil Cuttings	6	$	1,100	/Each	$	6,600	3
	f	Disposal of Hazardous Soil Cuttings	114	$	550	/Ton	$	62,700	3
	g	Transport of Hazardous Water	1	$	1,100	/Each	$	562	3
	h	Disposal of Hazardous Water	2300	$	0.8	/Gal	$	1,840	3
	i	Waste Characterization/Profiling	3	$	500	/Each	$	1,500	
		Subtotal - Waste Management					$	83,102	
		Total Subcontractor Cost w/10% Markup					$	687,396	

TOTAL WELL REPLACEMENT COST	$	762,221

Cost Source Reference

1 Verbal Quote from Cascade Drilling
2 Based on Quote from Water Development Corporation Dated 4/25/08
3 Verbal Quote from NRC Environmental

BOE-C6-0060127

Appendix J
Table 2.0
Cost Summary
Institutional Controls

Discount Rate 4%

Year	Activity	Cost (Undiscounted)	Cost (NPV)
1	Deed Restriction and Sign Installation - On Property	$ 100,000	$ 110,577
	Deed Restriction - Off Property (Former Boeing Realty Corp. to the North)	$ 15,000	
2	Deed Restriction Renewal (On and Off Property) and Fence/Signage Maintenance	$ 5,000	$ 4,623
3		$ 5,000	$ 4,445
4		$ 5,000	$ 4,274
5		$ 5,000	$ 4,110
6		$ 5,000	$ 3,952
7		$ 5,000	$ 3,800
8		$ 5,000	$ 3,653
9		$ 5,000	$ 3,513
10		$ 5,000	$ 3,378
11		$ 5,000	$ 3,248
12		$ 5,000	$ 3,123
13		$ 5,000	$ 3,003
14		$ 5,000	$ 2,887
15		$ 5,000	$ 2,776
16		$ 5,000	$ 2,670
17		$ 5,000	$ 2,567
18		$ 5,000	$ 2,468
19		$ 5,000	$ 2,373
20		$ 5,000	$ 2,282
21		$ 5,000	$ 2,194
22		$ 5,000	$ 2,110
23		$ 5,000	$ 2,029
24		$ 5,000	$ 1,951
25		$ 5,000	$ 1,876
26		$ 5,000	$ 1,803
27		$ 5,000	$ 1,734
28		$ 5,000	$ 1,667
29		$ 5,000	$ 1,603
30		$ 5,000	$ 1,542

Net Present Value at 30 Years = $ 192,229

Appendix J
Table 3.0
Cost Summary
Unsaturated Zone SVE (Not Coupled with Thermal Remedy)

Discount Rate 4%

Year	Activity	Detailed Cost Table	Cost (Undiscounted)	Cost (NPV)
1	Design	J-3.1 Design	$ 194,000	$ 186,538
2	System Construction	J-3.2 Well Construction	$ 365,252	$ 1,340,719
		J-3.3 Well Field Equipment Installation	$ 239,631	
		J-3.4 Treatment Equipment Installation	$ 695,778	
		J-3.5 Construction Management	$ 149,460	
3	Operation and Maintenance - Year 1	J-3.6 Annual Operations and Maintenance	$ 1,240,343	$ 1,102,661
4	Operation and Maintenance - Year 2		$ 834,487	$ 713,323
5	Operation and Maintenance - Year 3		$ 700,287	$ 575,585
6	Operation and Maintenance - Year 4		$ 619,657	$ 489,724
7	Verification and Abandonment	J-3.7 Well Abandonment	$ 111,927	$ 221,731
		J-3.8 Demobilization	$ 179,856	

Total NPV at 7 Years	**$ 4,630,281**
Total Undiscounted Cost	**$ 5,330,678**

Appendix J
Table 3.1
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Design

Item	Consultant Labor	Quantity	Unit Cost			Cost	
1	Project Manager	160	$	150	/Hour	$	24,000
2	Senior Engineer/Geologist	480	$	125	/Hour	$	60,000
3	Mid-Level Engineer/Geologist	600	$	100	/Hour	$	60,000
4	Junior/Field Engineer/Geologist	400	$	75	/Hour	$	30,000
5	Field Technician	0	$	75	/Hour	$	-
6	Clerical/Drafting	400	$	50	/Hour	$	20,000
	Consultant Labor					**$**	**194,000**

	TOTAL DESIGN COST	**$**	**194,000**

Appendix J
Table 3.2
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Well Construction

Item	Consultant Labor	Quantity	Unit Cost			Cost	Cost Ref.
1	Project Manager	40	$	150	/Hour	$ 6,000	
2	Senior Engineer/Geologist	40	$	125	/Hour	$ 5,000	
3	Mid-Level Engineer/Geologist	130	$	100	/Hour	$ 13,000	
4	Junior/Field Engineer/Geologist	200	$	75	/Hour	$ 15,000	
5	Field Technician	70	$	75	/Hour	$ 5,250	
6	Clerical/Drafting	40	$	50	/Hour	$ 2,000	
	Total Consultant Labor Cost					**$ 46,250**	

Item	Subcontractor Cost	Quantity	Unit Cost			Cost	Cost Ref.
7	**HSA Rig Mobilization**	1	$	1,200	/Each	**$ 1,200**	1
8	**Palos Verdes Sands SVE Wells (12" HSA Drilling to 45' bgs)**						
a	Install Well Constructed of 6" LCS Casing w/ 20' of SS Screen	1	$	8,500	/Each	$ 8,500	1
b	Forklift and Hopper Rental for Waste Handling	0.5	$	250	/Day	$ 125	1
c	Drill Crew per Diem	0.5	$	450	/Night	$ 225	1
d	Vehicle Usage	0.5	$	100	/Day	$ 50	
e	Equipment Rental and Supplies	0.5	$	500	/Day	$ 250	
f	Other Direct Costs	0.5	$	300	/Day	$ 150	
	Cost per Well					$ 9,300	
	Number of Wells (2 Wells Installed per Day)					7	
	Subtotal - PVS Wells					**$ 65,100**	

Appendix J
Table 3.2
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Well Construction

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
9		**UBA SVE Wells (12" HSA Drilling to 60 bgs)**					
	a	Install Well Constructed of 6" LCS Casing w/ 15' of SS Screen	1	$ 9,700	/Each	$ 9,700	1
	b	Forklift and Hopper Rental for Waste Handling	0.5	$ 250	/Day	$ 125	1
	c	Drill Crew per Diem	0.5	$ 450	/Night	$ 225	1
	d	Vehicle Usage	0.5	$ 100	/Day	$ 50	
	e	Equipment Rental and Supplies	0.5	$ 500	/Day	$ 250	
	f	Installation Permit	1	$ 201	/Each	$ 201	
	g	Other Direct Costs	0.5	$ 300	/Day	$ 150	
		Cost per Well				$ 10,701	
		Number of Wells (2 Wells Installed per Day)				16	
		Subtotal - UBA Wells				**$ 171,216**	
10		**Lab Analytical (Three PVS Borinngs and Four UBA Borings)**					
	a	Soil Analysis - Pesticides (EPA Method 8081A)	22	$ 90	/Sample	$ 1,980	2
	b	Soil Analysis - VOCs (EPA Method 8260B)	22	$ 95	/Sample	$ 2,090	2
	c	Soil Analysis - pCBSA (Modified EPA Method 314.0)	22	$ 80	/Sample	$ 1,760	2
	d	Water Analysis - Pesticides (EPA Method 8081A)	4	$ 90	/Sample	$ 360	2
	e	Water Analysis - VOCs (EPA Method 8260B)	4	$ 95	/Sample	$ 380	2
	f	Water Analysis - pCBSA (Modified EPA Method 314.0)	4	$ 80	/Sample	$ 320	2
		Total Lab Analytical (Extraction Wells)				**$ 6,890**	

Appendix J
Table 3.2
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost			Cost		Cost Ref.
11	**Waste Management**							
a	Waste Tank Rental	42	$	38	/Day	$	1,577	3
b	Waste Tank Rental Delivery - Mob and Demob	1	$	900	/Each	$	900	3
c	Waste Bin Rental	90	$	15	/Day	$	1,350	3
d	Waste Bin Rental Delivery - Mob and Demob	3	$	500	/Each	$	1,500	3
e	Transport of Hazardous Soil Cuttings	3	$	1,100	/Each	$	3,300	3
f	Disposal of Hazardous Soil Cuttings	60	$	550	/Ton	$	33,029	3
g	Transport of Hazardous Water	1	$	1,100	/Each	$	1,100	3
h	Disposal of Hazardous Water	2300	$	0.8	/Gal	$	1,840	3
i	Waste Characterization/Profiling	2	$	500	/Each	$	1,000	
	Subtotal - Waste Management					**$**	**45,596**	
	Total Subcontractor Cost w/10% Markup					**$**	**319,002**	
	TOTAL WELL CONSTRUCTION COST					**$**	**365,252**	

Cost Source Reference

1 Verbal Quote from Water Development Corporation
2 Verbal Quote from Test America
3 Verbal Quote from NRC Environmental

Appendix J
Table 3.3
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Well Field Equipment Installation

Item	Consultant Labor and Direct Costs	Quantity	Unit Cost			Cost	Cost Ref.
1	**Electrical Service Upgrade**	1	$	50,000	LS	$ 50,000	
2	**Extraction Well Assemblies**						
a	Static Pressure Gage	23	$	48	/Each	$ 1,104	1
b	Temperature Indicator	23	$	127	/Each	$ 2,921	1
c	Flow Sensor	23	$	121	/Each	$ 2,783	2
d	Differential Pressure Gage	23	$	315	/Each	$ 7,245	2
	Total Extraction Well Assemblies					$ 14,053	
3	**SVE Piping**						
a	8-Inch Carbon Steel Pipe and Fittings	760	$	94.71	LF	$ 71,980	3
b	6-Inch Carbon Steel Pipe and Fittings	760	$	67.65	LF	$ 51,414	3
	Total SVE Piping					$ 123,394	
4	**Pipe Supports**	152	$	200	LF	$ 30,400	
	DIRECT COSTS w/10% MARKUP					$ 239,631	
	TOTAL WELL FIELD EQUIPMENT INSTALLTION COST					$ 239,631	

Cost Source Reference

1 Grainger Catalog Price
2 Dwyer Instruments, Inc. Catalog Price
3 Cost in 2008 dollars based on 2006 RS Means and an assumed inflation rate if 3% per year

Appendix J
Table 3.4
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Treatment Equipment Installation

Item	Direct Costs	Quantity	Unit Cost			Cost		Cost Ref.
1	Mini RAE 3000 PID (Hand Held)	1	$	3,825	/Each	$	3,825	1
2	10,000-lb Vapor-Phase Carbon Vessel	4	$	32,000	/Each	$	128,000	2
3	Initial Carbon Fill (Virgin Coconut)	40,000	$	1.07	/lb	$	42,800	2
4	Oriface Plate and Transmitter	2	$	10,000	/Each	$	20,000	
5	Moister Separator	2	$	4,000	/Each	$	8,000	3
6	Transfer Pump (50 gpm)	2	$	536	/Each	$	1,072	4
7	1000 SCFM Positive Displacement Blower (for PVS)	1	$	30,000	/Each	$	30,000	5
8	1000 SCFM Liquid Ring Blower (Hi Vac for UBA)	1	$	80,000	/Each	$	80,000	5
9	Inline Stack PID	1	$	3,775	/Each	$	3,775	1
10	Static Pressure Gage	14	$	48	/Each	$	672	4
11	Temperature Indicator	9	$	127	/Each	$	1,143	4
12	Interconnecting Piping (10% of Carbon Vessel Cost)	1	$	12,800	LS	$	12,800	
13	Electrical Allowance (20% of elec components)	1	$	20,969	LS	$	20,969	
14	Control System Allowance (20% of elec components)	1	$	26,969	LS	$	26,969	
15	Treatment Plant Pad and Building	1	$	152,500	LS	$	152,500	6
16	Subcontractor Installation Cost	1	$	100,000	LS	$	100,000	
	TOTAL TREATMENT EQUIPMENT INSTALLATION COST w/10% MARKUP					**$**	**695,778**	

<u>Cost Source Reference</u>

1 Verbal Quote from RAE Systems
2 Based on July 1 2008 BakerCorp Quote
3 Verbal Quote from Enviro Supply and Services
4 Grainger Catalog Price
5 Yardley Pump and Vacuum Quote Dated July 18, 2008
6 Based on Building/Lab Site Improvements Cost for 350 gpm LGAC Adsorber System in 1998 Joint Groundwater Feasibility Study for the Montrose and Del Amo Sites

Appendix J
Table 3.5
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Construction Management

Item	Consultant Labor	Quantity	Unit Cost			Cost
1	Project Manager	48	$	150	/Hour	$ 7,200
2	Senior Engineer/Geologist	150	$	125	/Hour	$ 18,750
3	Mid-Level Engineer/Geologist	300	$	100	/Hour	$ 30,000
4	Junior/Field Engineer/Geologist	600	$	75	/Hour	$ 45,000
5	Field Technician	600	$	75	/Hour	$ 45,000
6	Clerical/Drafting	70	$	50	/Hour	$ 3,510
	TOTAL CONSTRUCTION MANAGEMENT COST					$ 149,460

Appendix J
Table 3.6
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Annual Operations and Maintenance

Item	Consultant Labor (Operations)	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	52	$ 150	/Hour	$ 7,800	
2	Senior Engineer/Geologist	52	$ 125	/Hour	$ 6,500	
3	Mid-Level Engineer/Geologist	208	$ 100	/Hour	$ 20,800	
4	Junior/Field Engineer/Geologist	520	$ 75	/Hour	$ 39,000	
5	Field Technician (20 Hours a week)	1,040	$ 75	/Hour	$ 78,000	
6	Clerical/Drafting	0	$ 50	/Hour	$ -	
	Consultant Labor Cost for Operations				**$ 152,100**	

Item	Consultant Labor (Reporting, H&S, and Data Mngt)	Quantity	Unit Cost		Cost	Cost Ref.
7	Project Manager	40	$ 150	/Hour	$ 6,000	
8	Senior Engineer/Geologist	80	$ 125	/Hour	$ 10,000	
9	Mid-Level Engineer/Geologist	160	$ 100	/Hour	$ 16,000	
10	Junior/Field Engineer/Geologist	160	$ 75	/Hour	$ 12,000	
11	Field Technician	0	$ 75	/Hour	$ -	
12	Clerical/Drafting	160	$ 50	/Hour	$ 8,000	
	Consultant labor for Reporting, H&S, Data Mngt, and Website Maintenance				**$ 52,000**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
13	**Turnkey VGAC Change-Out Service (incl. fresh VGAC and T&D of spent VGAC as Haz)**					
a	Year 1	480,000	$ 1.53	/lb VGAC	**$ 732,000**	1
b	Year 2	240,000	$ 1.53	/lb VGAC	**$ 366,000**	1
c	Year 3	160,000	$ 1.53	/lb VGAC	**$ 244,000**	1
d	Year 4	100,000	$ 1.53	/lb VGAC	**$ 152,500**	1
14	**Final Spent VGAC (40,000 lbs) Transportation and Disposal (Year 4)**	40,000	$ 0.46	/lb VGAC	$ 18,200	
	Total VGAC (Year 1)				**$ 732,000**	
	Total VGAC (Year 2)				**$ 366,000**	
	Total VGAC (Year 3)				**$ 244,000**	
	Total VGAC (Year 4)				**$ 170,700**	
15	**Lab Analytical and Monitoring**					
a	Summa Can Rental	116	$ 40	/Each	$ 4,640	2
b	Vapor VOCs Analysis (EPA TO-15)	116	$ 200	/Each	$ 23,200	2
c	Tedlar Bags	23	$ 10	/Each	$ 230	
	Total Lab Analytical and Monitoring				**$ 28,070**	

Appendix J
Table 3.6
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Annual Operations and Maintenance

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
16	**Miscellaneous - Year 1**					
a	Temporary Office 24'x60' Delivery and Setup	1	$ 2,939	/Each	$ 2,939	3
b	Temporary Office 24'x60' Rental	12	$ 1,030	/Month	$ 12,356	3
c	Temporary Office 24'x60' Demobilization	0	$ 1,746	/Each	$ -	3
d	Temporary Storage Trailer	12	$ 149	/Month	$ 1,784	4
e	Portable Toilet Delivery	1	$ 22	/Each	$ 22	5
f	Portable Toilet Rental	12	$ 76	/Month	$ 908	5
g	Miscellaneous Parts	12	$ 1,000	/Month	$ 12,000	
h	Fed Ex and Deliveries	12	$ 100	/Month	$ 1,200	
i	Temporary office comm. (internet, telephone, fax)	12	$ 1,000	/Month	$ 12,000	
j	Operator Truck Usage (One Truck per Operator)	260	$ 100	/Day/Truck	$ 26,000	
	Total Miscellaneous - Year 1				**$ 69,208**	
17	**Miscellaneous - Years 2 through 4**					
a	Temporary Office 24'x60' Delivery and Setup	0	$ 2,939	/Each	$ -	3
b	Temporary Office 24'x60' Rental	12	$ 1,030	/Month	$ 12,356	3
c	Temporary Office 24'x60' Demobilization	0	$ 1,746	/Each	$ -	3
d	Temporary Storage Trailer	12	$ 149	/Month	$ 1,784	4
e	Portable Toilet Delivery	0	$ 22	/Each	$ -	5
f	Portable Toilet Rental	12	$ 76	/Month	$ 908	5
g	Miscellaneous Parts	12	$ 1,000	/Month	$ 12,000	
h	Fed Ex and Deliveries	12	$ 100	/Month	$ 1,200	
i	Temporary office comm. (internet, telephone, fax)	12	$ 1,000	/Month	$ 12,000	
j	Operator Truck Usage (One Truck per Operator)	260	$ 100	/Day/Truck	$ 26,000	
	Total Miscellaneous - Years 2 through 4				**$ 66,248**	
	Total Subcontractor Cost - Year 1				**$ 829,278**	
	Total Subcontractor Cost - Year 2				**$ 460,318**	
	Total Subcontractor Cost - Year 3				**$ 338,318**	
	Total Subcontractor Cost - Year 4				**$ 265,018**	

Item	Utilities	Quantity	Unit Cost		Cost	Cost Ref.
18	**Electricity Usage**					
	Vacuum Blowers and Controls	1,186,958	$ 0.1045	/kWh	$ 124,037	6
	Total Utilities				**$ 124,037**	

Appendix J
Table 3.6
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Annual Operations and Maintenance

CONSULTANT LABOR COST	$	204,100
SUBCONTRACTOR COST w/10% MARKUP - YEAR 1	$	912,206
SUBCONTRACTOR COST w/10% MARKUP - YEAR 2	$	506,350
SUBCONTRACTOR COST w/10% MARKUP - YEAR 3	$	372,150
SUBCONTRACTOR COST w/10% MARKUP - YEAR 4	$	291,520
UTILITIES COST (NO MARKUP)	$	124,037
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 1	$	1,240,343
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 2	$	834,487
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 3	$	700,287
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 4	$	619,657

Cost Source Reference

1 Based on carbon costs associated with the Montrose Henderson SVE System
2 Verbal Quote from Calscience
3 Mobile Mini, Inc. Quote Dated October 11, 2007
4 Verbal Quote from Mobile Mini, Inc.
5 Verbal Quote from A-1 Coast Port-A-Toilet
6 Shedule A-3 LADWP Rate (Second Quarter 2008)

Appendix J
Table 3.7
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Well Abandonment

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	20	$ 150	/Hour	$ 3,000	
2	Senior Engineer/Geologist	40	$ 125	/Hour	$ 5,000	
3	Mid-Level Engineer/Geologist	40	$ 100	/Hour	$ 4,000	
4	Junior/Field Engineer/Geologist	180	$ 75	/Hour	$ 13,500	
5	Field Technician	40	$ 75	/Hour	$ 3,000	
6	Clerical/Drafting	40	$ 50	/Hour	$ 2,000	
	Total Consultant Labor Cost				**$ 30,500**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Mobilization/Demobilization of Drill Rig**	1	$ 2,000	/LS	**$ 2,000**	1
8	**Abandon PVS SVE Wells**					
a	Drill out well materials	5	$ 65	/Foot	$ 325	1
b	Pressure grout well	45	$ 30	/Foot	$ 1,350	1
c	Forklift and mini-hopper	0.5	$ 500	/Day	$ 250	1
d	Abandonment Crew per Diem	0.5	$ 200	/Night	$ 100	1
e	Vehicle Usage	0.5	$ 100	/Day	$ 50	
f	Equipment Rental and Supplies	0.5	$ 150	/Day	$ 75	
g	Other Direct Costs	0.5	$ 150	/Day	$ 75	
	Cost per Well				$ 2,225	
	Number of Wells (2 Wells Abandoned per Day)				7	
	Total for Extraction Well Adandonment				**15,575**	

Appendix J
Table 3.7
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Well Abandonment

Item	Subcontractor Cost	Quantity	Unit Cost			Cost	Cost Ref.
9	**Abandon UBA SVE Wells**						
a	Drill out well materials	5	$	65	/Foot	$ 325	1
b	Pressure grout well	60	$	30	/Foot	$ 1,800	1
c	Forklift and mini-hopper	0.5	$	500	/Day	$ 250	1
d	Abandonment Crew per Diem	0.5	$	200	/Night	$ 100	1
e	Vehicle Usage	0.5	$	100	/Day	$ 50	
f	Equipment Rental and Supplies	0.5	$	150	/Day	$ 75	
g	Other Direct Costs	0.5	$	150	/Day	$ 75	
	Cost per Well					$ 2,675	
	Number of Wells (2 Wells Abandoned per Day)					16	
	Total for Injection Well Abandonment					**42,800**	
10	**Waste Management**						
a	Waste Tank Rental	42	$	38	/Day	$ 1,577	2
b	Waste Tank Rental Delivery - Mob and Demob	1	$	900	/Each	$ 900	2
c	Waste Bin Rental	42	$	15	/Day	$ 623	2
d	Waste Bin Rental Delivery - Mob and Demob	1	$	500	/Each	$ 500	2
e	Transport and Disposal/Recycling of Steel	1	$	1,100	/Load	$ 1,100	
f	Transport of Hazardous Soil Cuttings	1	$	1,100	/Each	$ 1,100	2
g	Disposal of Hazardous Soil Cuttings	7.11	$	550	/Ton	$ 3,910	2
h	Transport of Hazardous Water	1	$	1,100	/Each	$ 1,100	2
i	Disposal of Hazardous Water	2300	$	0.8	/Gal	$ 1,840	2
j	Waste Characterization/Profiling	2	$	500	/Each	$ 1,000	
	Total Waste Management					**$ 13,650**	
	Total Subcontractor Cost w/10% Markup					**$ 81,427**	

TOTAL WELL ABANDONMENT COST	**$ 111,927**

Cost Source Reference
1 Verbal Quote from Water Development Corporation
2 Verbal Quote from NRC Environmental Services

Appendix J
Table 3.8
Detailed Cost, Unsaturated Zone SVE (Not Coupled with Thermal Remedy)
Demobilization

Item	Consultant Labor	Quantity	Unit Cost			Cost		Cost Ref.
1	Project Manager	12	$	150	/Hour	$	1,755	
2	Senior Engineer/Geologist	30	$	125	/Hour	$	3,750	
3	Mid-Level Engineer/Geologist	80	$	100	/Hour	$	8,000	
4	Junior/Field Engineer/Geologist	235	$	75	/Hour	$	17,625	
5	Field Technician	105	$	75	/Hour	$	7,898	
6	Clerical/Drafting	35	$	50	/Hour	$	1,755	
	Consultant Labor Cost					**$**	**40,783**	

Item	Subcontractor Cost	Quantity	Unit Cost			Cost		Cost Ref.
7	**Remove Purchased Treatment Equipment**	1	$	90,000	/LS	**$**	**90,000**	
8	**Demob Office Trailer**	1	$	1,746	LS	**$**	**1,746**	
9	**Close-Out Borings**							
a	Drilling and backfilling (6-Inch Sonic to 45 feet bgs at $65/foot)	3	$	2,925	/Boring	$	8,775	1
b	Drilling and backfilling (6-Inch Sonic to 60 feet bgs at $65/foot)	4	$	3,900	/Boring	$	15,600	1
c	Disposal of Hazardous Soil Cuttings	4.4	$	550	/Ton	$	2,429	2
d	Transportation of Hazardous Soil Cuttings	1	$	1,100	/Each	$	1,100	2
e	Waste Bin Rental Delivery - Mob and Demob	1	$	500	/Each	$	500	2
f	Waste Bin Rental	30	$	15	/Day	$	450	2
g	Soil Pesticides (EPA Method 8081A)	22	$	90	/Sample	$	1,980	3
h	Soil VOCs (EPA Method 8260B)	22	$	95	/Sample	$	2,090	3
i	Soil pCBSA (Modified EPA Method 314.0)	22	$	80	/Sample	$	1,760	3
	Total for Close-Out Borings					**$**	**34,684**	
	Total Subcontractor Cost w/10% Markup					**$**	**139,073**	

	TOTAL DEMOBILIZATION COST	**$**	**179,856**

Cost Source Reference
1 Water Development Corporation Quote Dated 10/09/08
2 Verbal Quote from NRC Environmental Services
3 Verbal Quote from Test America

Appendix J
Table 4.0
Cost Summary
Hydraulic Displacement
50-Foot Well Spacing

Discount Rate 4%

Year	Activity	Detailed Cost Table	Cost (Undiscounted)	Cost (NPV)
1	Design	J-4.1 Design	$ 460,439	$ 442,730
2	System Construction	J-4.2 Well Construction	$ 1,146,569	$ 2,139,610
		J-4.3 Well Field Equipment Installation	$ 519,594	
		J-4.4 DNAPL Colletion Equipment Installation	$ 455,511	
		J-4.5 Construction Management	$ 192,529	
3	Operation and Maintenance - Year 1	J-4.6 Annual Operations and Maintenance	$ 747,047	$ 664,122
4	Operation and Maintenance - Year 2		$ 699,330	$ 597,790
5	Operation and Maintenance - Year 3		$ 675,512	$ 555,221
6	Operation and Maintenance - Year 4		$ 668,784	$ 528,550
7	Operation and Maintenance - Year 5		$ 663,305	$ 504,057
8	Verification and Abandonment	J-4.7 Well Abandonment	$ 260,506	$ 373,838
		J-4.8 Demobilization	$ 251,116	

Total NPV at 8 Years	**$ 5,805,919**
Total Undiscounted Cost	**$ 6,740,243**

Appendix J
Table 4.1
Detailed Cost, Hydraulic Displacement
Design

Item	Consultant Labor	Quantity	Unit Cost			Cost
1	Project Manager	450	$	150	/Hour	$ 67,439
2	Senior Engineer/Geologist	830	$	125	/Hour	$ 103,750
3	Mid-Level Engineer/Geologist	1,780	$	100	/Hour	$ 178,000
4	Junior/Field Engineer/Geologist	890	$	75	/Hour	$ 66,750
5	Field Technician	0	$	75	/Hour	$ -
6	Clerical/Drafting	890	$	50	/Hour	$ 44,500
	Consultant Labor					**$ 460,439**

TOTAL DESIGN COST	**$ 460,439**

Appendix J
Table 4.2
Detailed Cost, Hydraulic Displacement
Well Construction

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	200	$ 150	/Hour	$ 30,000	
2	Senior Engineer/Geologist	200	$ 125	/Hour	$ 25,000	
3	Mid-Level Engineer/Geologist	700	$ 100	/Hour	$ 70,000	
4	Junior/Field Engineer/Geologist	1,080	$ 75	/Hour	$ 81,000	
5	Field Technician	340	$ 75	/Hour	$ 25,500	
6	Clerical/Drafting	200	$ 50	/Hour	$ 10,000	
	Total Consultant Labor Cost				**$ 241,500**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Extraction Wells (12" HSA Drilling to 105' bgs)**					
a	Install Well Constructed of 6" LCS Casing w/ 40' of SS Screen and 5-foot Sump	1	$ 12,000	/Each	$ 12,000	1
b	Forklift and Hopper Rental for Waste Handling	1	$ 250	/Day	$ 250	1
c	Drill Crew per Diem	1	$ 450	/Night	$ 450	1
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
f	Installation Permit	1	$ 201	/Each	$ 201	
g	Other Direct Costs	1	$ 300	/Day	$ 300	
	Cost per Well				$ 13,801	
	Number of Wells (1 Well Installed per Day)				14	
	Subtotal - Extraction Wells				**$ 193,214**	
8	**Lab Analytical (Seven Extraction Well Borings)**					
a	Soil Analysis - Pesticides (EPA Method 8081A)	42	$ 90	/Sample	$ 3,780	2
b	Soil Analysis - VOCs (EPA Method 8260B)	42	$ 95	/Sample	$ 3,990	2
c	Soil Analysis - pCBSA (Modified EPA Method 314.0)	42	$ 80	/Sample	$ 3,360	2
d	Water Analysis - Pesticides (EPA Method 8081A)	7	$ 90	/Sample	$ 630	2
e	Water Analysis - VOCs (EPA Method 8260B)	7	$ 95	/Sample	$ 665	2
f	Water Analysis - pCBSA (Modified EPA Method 314.0)	7	$ 80	/Sample	$ 560	2
	Total Lab Analytical (Extraction Wells)				**$ 12,985**	

Appendix J
Table 4.2
Detailed Cost, Hydraulic Displacement
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
9	**Injection Wells (12" HSA Drilling to 100.5' bgs)**					
a	HSA Drilling	100.5	$ 30	/Foot	$ 3,015	3
b	Install 4-Inch Stainless Steel Wire Wrap Screen	40	$ 80	/Foot	$ 3,200	3
c	Install 4-Inch LCS Casing	60	$ 20	/Foot	$ 1,200	3
d	Bore hole materials (Cement, bentonite, sand, and concrete)	100.5	$ 12	/Foot	$ 1,206	3
e	Forklift and Hopper Rental for Waste Handling	1	$ 250	/Day	$ 250	1
f	Drill Crew per Diem	1	$ 450	/Night	$ 450	1
g	Vehicle Usage	1	$ 100	/Day	$ 100	
h	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
i	Installation Permit	1	$ 201	/Each	$ 201	
j	Other Direct Costs	1	$ 300	/Day	$ 300	
	Cost per Well				$ 10,422	
	Number of Wells (1 Well Installed per Day)				23	
	Subtotal - Injecton Wells				**$ 239,706**	
10	**Develop Extraction and Injection Wells**					
a	Development Rig	1	$ 2,000	/Day	$ 2,000	1
b	Development Crew per Diem	1	$ 200	/Night	$ 200	4
c	Vehicle Usage	1	$ 100	/Day	$ 100	
d	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
e	Other Direct Costs	1	$ 300	/Day	$ 300	
	Cost per Well				$ 3,100	
	Number of Wells (1 Well Developed per Day)				37	
	Subtotal - Develop Extraction and Injection Wells				**$ 114,700**	
11	**BFS Monitoring Well Installation** (4 Days per Well for Installation and Development)	2	$ 54,000	/Well	**$ 108,000**	5

Appendix J
Table 4.2
Detailed Cost, Hydraulic Displacement
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost			Cost		Cost Ref.
12	**Waste Management**							
a	Waste Tank Rental	112	$	38	/Day	$	4,256	6
b	Waste Tank Rental Delivery - Mob and Demob	1	$	900	/Each	$	900	6
c	Waste Bin Rental	313	$	15	/Day	$	4,697	6
d	Waste Bin Rental Delivery - Mob and Demob	10	$	500	/Each	$	5,219	6
e	Transport of Hazardous Soil Cuttings	10	$	1,100	/Each	$	11,483	6
f	Disposal of Hazardous Soil Cuttings	209	$	550	/Ton	$	114,827	6
g	Transport of Hazardous Water	3	$	1,100	/Each	$	2,762	6
h	Disposal of Hazardous Water	11300	$	0.8	/Gal	$	9,040	6
i	Waste Characterization/Profiling	2	$	500	/Each	$	1,000	
	Subtotal - Waste Management					**$**	**154,185**	
	Total Subcontractor Cost w/10% Markup					**$**	**905,069**	
	TOTAL WELL CONSTRUCTION COST					**$**	**1,146,569**	

Cost Source Reference

1 Verbal Quote from Cascade Drilling
2 Verbal Quote from Test America
3 Water Development Corporation Quote Dated 10/09/08
4 Cascade Drilling Quote Dated July 15, 2008
5 Verbal Quote from Water Development Corporation
6 Verbal Quote from NRC Environmental

Appendix J
Table 4.3
Detailed Cost, Hydrualic Displacement
Well Field Equipment Installation

Item	Consultant Labor and Direct Costs	Quantity	Unit Cost			Cost		Cost Ref.
1	**Electrical Service Upgrade**	1	$	50,000	LS	$	50,000	
2	**Extraction Well Assemblies**							
a	Well Head Assemblies	18	$	500	Each	$	9,000	
b	Groundwater Extraction Pump (Electric Submersible)	18	$	597.54	Each	$	10,756	1
c	Armored Electrical Cable	1800	$	4.89	Foot	$	8,802	2
d	Teflon Discharge Tubing (5/8" OD)	3600	$	7.85	Foot	$	28,260	2
e	DNAPL Extraction Pump (Pneumatic)	18	$	2,448.85	Each	$	44,079	3
f	Downwell Air Supply Hose (3/8" OD Teflon)	1800	$	3.76	LF	$	6,768	2
g	Downwell Air Exhaust Hose (1/2" OD Teflon)	1800	$	5.43	LF	$	9,774	2
h	Static Pressure Gage	36	$	48	/Each	$	1,728	4
i	Temperature Indicator	18	$	127	/Each	$	2,286	4
j	Flow Sensor	18	$	121	/Each	$	2,178	5
k	Differential Pressure Gage	18	$	315	/Each	$	5,670	5
	Total Extraction Well Assemblies					$	129,301	
3	**Injection Well Assemblies**							
a	Well Head Assemblies	23	$	300	Each	$	6,900	
b	Static Pressure Gage	23	$	48	/Each	$	1,104	4
c	Temperature Indicator	23	$	127	/Each	$	2,921	4
d	Flow Sensor	23	$	121	/Each	$	2,783	5
e	Differential Pressure Gage	23	$	315	/Each	$	7,245	5
	Total Injection Well Assemblies					$	20,953	
4	**Field Technician - Extraction and Injection Well Assembly Construction and Installation** (Consultant Labor - Not Subject to Markup)	330	$	75	Hour	$	24,750	

Appendix J
Table 4.3
Detailed Cost, Hydrualic Displacement
Well Field Equipment Installation

Item	Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
5	**Groundwater and DNAPL Extraction Piping and Electrical (Installed)**					
a	4-Inch Carbon Steel Pipe and Fittings	220	$ 51.45	LF	$ 11,320	6
b	2-Inch Carbon Steel Pipe and Fittings	2398	$ 23.87	LF	$ 57,241	6
c	1.5-Inch Carbon Steel Pipe and Fittings	600	$ 18.51	LF	$ 11,108	6
d	3.5-Inch Galvanized Steel Pipe	110	$ 33.42	LF	$ 3,676	6
e	3-Inch Galvanized Steel Pipe	1199	$ 27.05	LF	$ 32,436	6
f	2.5-Inch Galvanized Steel Pipe	290	$ 22.28	LF	$ 6,461	6
g	Electrical Wire	1599	$ 5.46	LF	$ 8,736	6
	Total Groundwater and DNAPL Extraction Piping and Electrical				**$ 130,978**	
6	**Injection Piping (Installed)**					
a	4-Inch Carbon Steel Pipe and Fittings	110	$ 51.45	LF	$ 5,660	6
b	2-Inch Carbon Steel Pipe and Fittings	1234	$ 23.87	LF	$ 29,456	6
c	1.5-Inch Carbon Steel Pipe and Fittings	473	$ 18.51	LF	$ 8,760	6
	Total Injection Piping				**$ 43,875**	
7	**Compressed Air Pipe and Fittings (2-Inch Carbon Steel) (Installed)**	1609	$ 23.87	LF	**$ 38,407**	6
8	**Pipe Supports**	182	$ 200	LF	**$ 36,343**	
	CONSULTANT LABOR COST				**$ 24,750**	
	DIRECT COSTS w/10% MARKUP				**$ 494,844**	
	TOTAL WELL FIELD EQUIPMENT INSTALLTION COST				**$ 519,594**	

Cost Source Reference

1 Shaw Pump and Supply, Inc. Quote Dated September 24, 2008
2 McMaster-Carr Catalog Price
3 QED Environmental Systems, Inc. Quote Dated September 25, 2008
4 Grainger Catalog Price
5 Dwyer Instruments, Inc. Catalog Price
6 Cost in 2008 dollars based on 2006 RS Means and an assumed inflation rate if 3% per year

Appendix J
Table 4.4
Detailed Cost, Hydraulic Displacement
DNAPL Collection Equipment Installation

Item	Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
1	240 Gallon Decanter	1	$ 3,344	/Each	$ 3,344	1
2	200 GPM DNAPL/Water Separator	1	$ 124,365	/Each	$ 124,365	2
3	Groundwater Holding Tank	1	$ 50,000	/Each	$ 50,000	
4	Dual Filter Bag System	1	$ 13,000	/Each	$ 13,000	3
5	Air Compressor (563 CFM Rotary Screw)	1	$ 36,185	/Each	$ 36,185	4
6	500-Gallon Collection Tank	1	$ 2,078	/Each	$ 2,078	5
7	Transfer Pump (50 gpm)	3	$ 536	/Each	$ 1,607	6
8	Transfer Pump (200 gpm)	1	$ 1,773	/Each	$ 1,773	6
9	Collection Plant Pad and Building	1	$ 106,750	/LS	$ 106,750	7
10	Subcontractor Installation Cost	1	$ 75,000	/LS	$ 75,000	
	TOTAL TREATMENT EQUIPMENT INSTALLATION COST w/10% MARKUP				**$ 455,511**	

Cost Source Reference

1 Highland Tank and Manufacturing Co. Quote Dated September 26, 2008
2 Pan America Environmental Quote Dated July 18, 2008
3 Verbal Quote from BakerCorp
4 Ingersoll Rand Quote Dated September 25, 2008
5 Harrington Plastic Catalog Price
6 Grainger Catalog Price
7 Assumed to be 30% less than treatment plant pad and building for groundwater treatment

Appendix J
Table 4.5
Detailed Cost, Hydraulic Displacement
Construction Management

Item	Consultant Labor	Quantity	Unit Cost			Cost	
1	Project Manager	175	$	150	/Hour	$	26,220
2	Senior Engineer/Geologist	175	$	125	/Hour	$	21,850
3	Mid-Level Engineer/Geologist	350	$	100	/Hour	$	34,959
4	Junior/Field Engineer/Geologist	700	$	75	/Hour	$	52,500
5	Field Technician	700	$	75	/Hour	$	52,500
6	Clerical/Drafting	90	$	50	/Hour	$	4,500
	TOTAL CONSTRUCTION MANAGEMENT COST					**$**	**192,529**

BOE-C6-0060151

Appendix J
Table 4.6
Detailed Cost, Hydraulic Displacement
Annual Operations and Maintenance

Item	Consultant Labor (Operations)	Quantity	Unit Cost			Cost	Cost Ref.
1	Project Manager	156	$	150	/Hour	$ 23,400	
2	Senior Engineer/Geologist	156	$	125	/Hour	$ 19,500	
3	Mid-Level Engineer/Geologist	208	$	100	/Hour	$ 20,800	
4	Junior/Field Engineer/Geologist	1,040	$	75	/Hour	$ 78,000	
5	Field Technician (1 Full Time Equivalent)	2,080	$	75	/Hour	$ 156,000	
6	Clerical/Drafting	0	$	50	/Hour	$ -	
	Consultant Labor Cost for Operations					**$ 297,700**	

Item	Consultant Labor (Reporting, H&S, Data Mngt, and Website Maintenance	Quantity	Unit Cost			Cost	Cost Ref.
7	Project Manager	20	$	150	/Hour	$ 3,000	
8	Senior Engineer/Geologist	80	$	125	/Hour	$ 10,000	
9	Mid-Level Engineer/Geologist	130	$	100	/Hour	$ 13,000	
10	Junior/Field Engineer/Geologist	520	$	75	/Hour	$ 39,000	
11	Field Technician	0	$	75	/Hour	$ -	
12	Clerical/Drafting	240	$	50	/Hour	$ 12,000	
	Consultant labor for Reporting, H&S, Data Mngt, and Website Maintenance					**$ 77,000**	

Appendix J
Table 4.6
Detailed Cost, Hydraulic Displacement
Annual Operations and Maintenance

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
13		**Waste Management**					
	a	Filtration Generated Waste Disposal (Listed Waste for Incineration)	78,600	$ 0.25	/lb	$ 19,650	1
	b	Filtration Generated Waste Transportation	4	$ 2,800	/Load	$ 11,200	1
		DNAPL T&D - Year 1					
		Tank Loads					
	c	Transportation	4	$ 3,650	/Load	$ 14,600	1
	d	Disposal	126,746	$ 0.50	/lb	$ 63,373	1
		DNAPL T&D - Year 2					
		Tank Loads					
	e	Transportation	4	$ 3,650	/Load	$ 14,600	1
	f	Disposal	45,908	$ 0.50	/lb	$ 22,954	1
		DNAPL T&D - Year 3					
		55-Gallon Drums					
	g	Transportation and Disposal	26	$ 612	/drum	$ 15,901	2
		DNAPL T&D - Year 4					
		55-Gallon Drums					
	h	Transportation and Disposal	16	$ 612	/drum	$ 9,785	2
		DNAPL T&D - Year 5					
		55-Gallon Drums					
	i	Transportation and Disposal	5	$ 612	/drum	$ 3,058	2
		Total Waste Management - Year 1				**$ 108,823**	
		Total Waste Management - Year 2				**$ 68,404**	
		Total Waste Management - Year 3				**$ 46,751**	
		Total Waste Management - Year 4				**$ 40,635**	
		Total Waste Management - Year 5				**$ 33,908**	

Appendix J
Table 4.6
Detailed Cost, Hydraulic Displacement
Annual Operations and Maintenance

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
14		**Lab Analytical and Monitoring**					
	c	Water Analysis - Pesticides (EPA Method 8081A)	96	$ 90	/Each	$ 8,640	3
	d	Water Analysis - VOCs (EPA Method 8260B)	96	$ 95	/Each	$ 9,120	3
	e	Water Analysis - pCBSA (Modifed EPA Method 314.0)	96	$ 80	/Each	$ 7,680	3
		Total Lab Analytical and Monitoring				**$ 25,440**	
15		**Miscellaneous - Year 1**					
	a	Temporary Office 24'x60' Delivery and Setup	1	$ 2,939	/Each	$ 2,939	4
	b	Temporary Office 24'x60' Rental	12	$ 1,030	/Month	$ 12,356	4
	c	Temporary Office 24'x60' Demobilization	0	$ 1,746	/Each	$ -	4
	d	Temporary Storage Trailer	12	$ 149	/Month	$ 1,784	5
	e	Portable Toilet Delivery	1	$ 22	/Each	$ 22	6
	f	Portable Toilet Rental	12	$ 76	/Month	$ 908	6
	g	Well and Pump Maintenance Parts	12	$ 5,000	/Month	$ 60,000	
	h	Fed Ex and Deliveries	52	$ 100	/Week	$ 5,200	
	i	Temporary office comm. (internet, telephone, fax)	12	$ 1,000	/Month	$ 12,000	
	j	Operator Truck Usage (One Truck per Operator)	260	$ 100	/Day/Truck	$ 26,000	
		Total Miscellaneous - Year 1				**$ 121,208**	

Appendix J
Table 4.6
Detailed Cost, Hydraulic Displacement
Annual Operations and Maintenance

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
16		**Miscellaneous - Years 2 through 4**					
	a	Temporary Office 24'x60' Delivery and Setup	0	$ 2,939	/Each	$ -	4
	b	Temporary Office 24'x60' Rental	12	$ 1,030	/Month	$ 12,356	4
	c	Temporary Office 24'x60' Demobilization	0	$ 1,746	/Each	$ -	4
	d	Temporary Storage Trailer	12	$ 149	/Month	$ 1,784	5
	e	Portable Toilet Delivery	0	$ 22	/Each	$ -	6
	f	Portable Toilet Rental	12	$ 76	/Month	$ 908	6
	g	Well and Pump Maintenance Parts	12	$ 5,000	/Month	$ 60,000	
	h	Fed Ex and Deliveries	52	$ 100	/Week	$ 5,200	
	i	Temporary office comm. (internet, telephone, fax)	12	$ 1,000	/Month	$ 12,000	
	j	Operator Truck Usage (One Truck per Operator)	260	$ 100	/Day/Truck	$ 26,000	
		Total Miscellaneous - Years 2 through 4				**$ 118,248**	
17		**Miscellaneous - Year 5**					
	a	Temporary Office 24'x60' Delivery and Setup	0	$ 2,939	/Each	$ -	4
	b	Temporary Office 24'x60' Rental	12	$ 1,030	/Month	$ 12,356	4
	c	Temporary Office 24'x60' Demobilization	1	$ 1,746	/Each	$ 1,746	4
	d	Temporary Storage Trailer	12	$ 149	/Month	$ 1,784	5
	e	Portable Toilet Delivery	0	$ 22	/Each	$ -	6
	f	Portable Toilet Rental	12	$ 76	/Month	$ 908	6
	g	Well and Pump Maintenance Parts	12	$ 5,000	/Month	$ 60,000	
	h	Fed Ex and Deliveries	52	$ 100	/Week	$ 5,200	
	i	Temporary office comm. (internet, telephone, fax)	12	$ 1,000	/Month	$ 12,000	
	j	Operator Truck Usage (One Truck per Operator)	260	$ 100	/Day/Truck	$ 26,000	
		Total Miscellaneous - Year 5				**$ 119,994**	

Appendix J
Table 4.6
Detailed Cost, Hydraulic Displacement
Annual Operations and Maintenance

	Total Subcontractor Cost - Year 1	**$ 255,471**	
	Total Subcontractor Cost - Year 2	**$ 212,092**	
	Total Subcontractor Cost - Year 3	**$ 190,439**	
	Total Subcontractor Cost - Year 4	**$ 184,323**	
	Total Subcontractor Cost - Year 5	**$ 179,342**	

Item	Utilities	Quantity	Unit Cost		Cost	Cost Ref.
18	**Electricity Usage**					
a	HiPOx Sytem	0	$ 0.1045	/kWh	$ -	7
b	Air Compressor and Pumps	873,961	$ 0.1045	/kWh	$ 91,329	7
	Total Utilities				**$ 91,329**	

	CONSULTANT LABOR COST	**$ 374,700**	
	SUBCONTRACTOR COST w/10% MARKUP - YEAR 1	**$ 281,018**	
	SUBCONTRACTOR COST w/10% MARKUP - YEAR 2	**$ 233,301**	
	SUBCONTRACTOR COST w/10% MARKUP - YEAR 3	**$ 209,483**	
	SUBCONTRACTOR COST w/10% MARKUP - YEAR 4	**$ 202,756**	
	SUBCONTRACTOR COST w/10% MARKUP - YEAR 5	**$ 197,276**	
	UTILITIES COST (NO MARKUP)	**$ 91,329**	

Appendix J
Table 4.6
Detailed Cost, Hydraulic Displacement
Annual Operations and Maintenance

TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 1	**$**	**747,047**
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 2	**$**	**699,330**
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 3	**$**	**675,512**
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 4	**$**	**668,784**
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 5	**$**	**663,305**

Cost Source Reference

1 Clean Harbors Quote Dated October 10, 2007
2 Verbal Quote from Clean Harbors
3 Verbal Quote from Test America
4 Mobile Mini, Inc. Quote Dated October 11, 2007
5 Verbal Quote from Mobile Mini, Inc.
6 Verbal Quote from A-1 Coast Port-A-Toilet
7 Shedule A-3 LADWP Rate (Second Quarter 2008)

Appendix J
Table 4.7
Detailed Cost, Hydraulic Displacement
Well Abandonment

Item	Consultant Labor	Quantity	Unit Cost			Cost		Cost Ref.
1	Project Manager	20	$	150	/Hour	$	3,000	
2	Senior Engineer/Geologist	90	$	125	/Hour	$	11,250	
3	Mid-Level Engineer/Geologist	90	$	100	/Hour	$	9,000	
4	Junior/Field Engineer/Geologist	330	$	75	/Hour	$	24,750	
5	Field Technician	90	$	75	/Hour	$	6,750	
6	Clerical/Drafting	90	$	50	/Hour	$	4,500	
	Total Consultant Labor Cost					**$**	**59,250**	

Item	Subcontractor Cost	Quantity	Unit Cost			Cost		Cost Ref.
1	**Mobilization/Demobilization of Drill Rig**	1	$	2,000	/LS	**$**	**2,000**	1
2	**Abandon Extraction Wells**							
a	Drill out well materials	5	$	65	/Foot	$	325	1
b	Pressure grout well	105	$	30	/Foot	$	3,150	1
c	Forklift and mini-hopper	0.5	$	500	/Day	$	250	1
d	Abandonment Crew per Diem	0.5	$	200	/Night	$	100	1
e	Vehicle Usage	0.5	$	100	/Day	$	50	
f	Equipment Rental and Supplies	0.5	$	150	/Day	$	75	
g	Other Direct Costs	0.5	$	150	/Day	$	75	
	Cost per Well					$	4,025	
	Number of Wells (2 Wells Abandoned per Day)						18	
	Total for Extraction Well Adandonment						**72,450**	

BOE-C6-0060158

Appendix J
Table 4.7
Detailed Cost, Hydraulic Displacement
Well Abandonment

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
3	**Abandon Injection Wells**					
a	Drill out well materials	5	$ 65	/Foot	$ 325	1
b	Pressure grout well	100.5	$ 30	/Foot	$ 3,015	1
c	Forklift and mini-hopper	0.5	$ 500	/Day	$ 250	1
d	Abandonment Crew per Diem	0.5	$ 200	/Night	$ 100	1
e	Vehicle Usage	0.5	$ 100	/Day	$ 50	
f	Equipment Rental and Supplies	0.5	$ 150	/Day	$ 75	
g	Other Direct Costs	0.5	$ 150	/Day	$ 75	
	Cost per Well				$ 3,890	
	Number of Wells (2 Wells Abandoned per Day)				23	
	Total for Injection Well Abandonment				**89,470**	
Item	**Subcontractor Cost**	**Quantity**	**Unit Cost**		**Cost**	**Cost Ref.**
4	**Waste Management**					
a	Waste Tank Rental	51	$ 38	/Day	$ 1,919	2
b	Waste Tank Rental Delivery - Mob and Demob	1	$ 900	/Each	$ 900	2
c	Waste Bin Rental	51	$ 15	/Day	$ 758	2
d	Waste Bin Rental Delivery - Mob and Demob	1	$ 500	/Each	$ 500	2
e	Transport and Disposal/Recycling of Steel	1	$ 1,100	/Load	$ 1,100	
f	Transport of Hazardous Soil Cuttings	1	$ 1,100	/Each	$ 1,100	2
g	Disposal of Hazardous Soil Cuttings	13	$ 550	/Ton	$ 7,384	2
h	Transport of Hazardous Water	1	$ 1,100	/Each	$ 1,100	2
i	Disposal of Hazardous Water	4100	$ 0.8	/Gal	$ 3,280	2
j	Waste Characterization/Profiling	2	$ 500	/Each	$ 1,000	
	Total Waste Management				**$ 19,040**	
	Total Subcontractor Cost w/10% Markup				**$ 201,256**	

	TOTAL WELL ABANDONMENT COST	**$ 260,506**

Cost Source Reference

1 Verbal Quote from Water Development Corporation
2 Verbal Quote from NRC Environmental Services

Appendix J
Table 4.8
Detailed Cost, Hydraulic Displacement
Demobilization

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	20	$ 150	/Hour	$ 3,000	
2	Senior Engineer/Geologist	40	$ 125	/Hour	$ 5,000	
3	Mid-Level Engineer/Geologist	110	$ 100	/Hour	$ 11,000	
4	Junior/Field Engineer/Geologist	325	$ 75	/Hour	$ 24,375	
5	Field Technician	130	$ 75	/Hour	$ 9,768	
6	Clerical/Drafting	45	$ 50	/Hour	$ 2,250	
	Consultant Labor Cost				**$ 55,393**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Remove Purchased Treatment Equipment**	1	$ 101,000	/LS	**$ 101,000**	
8	**Close-Out Borings**					
a	Drilling and backfilling (6-Inch Sonic to 105 feet bgs at $65/foot)	8	$ 6,825	/Boring	$ 54,600	1
b	Disposal of Hazardous Soil Cuttings	9.9	$ 550	/Ton	$ 5,440	2
c	Transportation of Hazardous Soil Cuttings	1	$ 1,100	/Each	$ 1,100	2
d	Waste Bin Rental Delivery - Mob and Demob	1	$ 500	/Each	$ 500	2
e	Waste Bin Rental	30	$ 15	/Day	$ 450	2
f	Soil Pesticides (EPA Method 8081A)	48	$ 90	/Sample	$ 4,320	3
g	Soil VOCs (EPA Method 8260B)	48	$ 95	/Sample	$ 4,560	3
h	Soil pCBSA (Modified EPA Method 314.0)	48	$ 80	/Sample	$ 3,840	3
i	Liquid Pesticides (EPA Method 8081A)	8	$ 90	/Sample	$ 720	3
j	Liquid VOCs (EPA Method 8260B)	8	$ 95	/Sample	$ 760	3
k	Liquid pCBSA (Modified EPA Method 314.0)	8	$ 80	/Sample	$ 640	3
	Total for Close-Out Borings				**$ 76,930**	
	Total Subcontractor Cost w/10% Markup				**$ 195,723**	

	TOTAL DEMOBILIZATION COST	**$ 251,116**

Cost Source Reference

1 Water Development Corporation Quote Dated 10/09/08
2 Verbal Quote from NRC Environmental Services
3 Verbal Quote from Test America

Appendix J
Table 5.0
Cost Summary
Hydraulic Displacement
25-Foot Well Spacing

Discount Rate 4%

Year	Activity	Detailed Cost Table	Cost (Undiscounted)	Cost (NPV)
1	Design	J-5.1 Design	$ 492,750	$ 473,798
2	System Construction	J-5.2 Well Construction	$ 1,911,079	$ 3,035,634
		J-5.3 Well Field Equipment Installation	$ 711,228	
		J-5.4 DNAPL Colletion Equipment Installation	$ 472,785	
		J-5.5 Construction Management	$ 188,250	
3	Operation and Maintenance - Year 1	J-5.6 Annual Operations and Maintenance	$ 806,077	$ 716,600
4	Operation and Maintenance - Year 2		$ 758,360	$ 648,249
5	Operation and Maintenance - Year 3		$ 734,542	$ 603,740
6	Operation and Maintenance - Year 4		$ 727,814	$ 575,202
7	Operation and Maintenance - Year 5		$ 722,335	$ 548,915
8	Verification and Abandonment	J-5.7 Well Abandonment	$ 435,214	$ 506,048
		J-5.8 Demobilization	$ 257,348	

Total NPV at 8 Years	$ 7,108,187
Total Undiscounted Cost	$ 8,217,782

Appendix J
Table 5.1
Detailed Cost, Hydraulic Displacement
Design

Item	Consultant Labor	Quantity	Unit Cost			Cost	Cost Ref.
1	Project Manager	485	$	150	/Hour	$ 72,750	
2	Senior Engineer/Geologist	890	$	125	/Hour	$ 111,250	
3	Mid-Level Engineer/Geologist	1,900	$	100	/Hour	$ 190,000	
4	Junior/Field Engineer/Geologist	950	$	75	/Hour	$ 71,250	
5	Field Technician	0	$	75	/Hour	$ -	
6	Clerical/Drafting	950	$	50	/Hour	$ 47,500	
	Consultant Labor					**$ 492,750**	

	TOTAL DESIGN COST	**$ 492,750**

Appendix J
Table 5.2
Detailed Cost, Hydraulic Displacement
Well Construction

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	370	$ 150	/Hour	$ 55,500	
2	Senior Engineer/Geologist	370	$ 125	/Hour	$ 46,250	
3	Mid-Level Engineer/Geologist	1,190	$ 100	/Hour	$ 119,000	
4	Junior/Field Engineer/Geologist	1,810	$ 75	/Hour	$ 135,750	
5	Field Technician	625	$ 75	/Hour	$ 46,875	
6	Clerical/Drafting	370	$ 50	/Hour	$ 18,500	
	Total Consultant Labor Cost				**$ 421,875**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Extraction Wells (12" HSA Drilling to 105' bgs)**					
a	Install Well Constructed of 6-Inch LCS Casing w/40' of SS Screen and 5-Foot Sump	1	$ 12,000	/Each	$ 12,000	1
b	Forklift and Hopper Rental for Waste Handling	1	$ 250	/Day	$ 250	1
c	Drill Crew per Diem	1	$ 450	/Night	$ 450	1
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
f	Installation Permit	1	$ 201	/Each	$ 201	
g	Other Direct Costs	1	$ 300	/Day	$ 300	
	Cost per Well				$ 13,801	
	Number of Wells (1 Well Installed per Day)				29	
	Subtotal - Extraction Wells				**$ 400,229**	
8	**Lab Analytical (Seven Extraction Well Borings)**					
a	Soil Analysis - Pesticides (EPA Method 8081A)	42	$ 90	/Sample	$ 3,780	2
b	Soil Analysis - VOCs (EPA Method 8260B)	42	$ 95	/Sample	$ 3,990	2
c	Soil Analysis - pCBSA (Modified EPA Method 314.0)	42	$ 80	/Sample	$ 3,360	2
d	Water Analysis - Pesticides (EPA Method 8081A)	7	$ 90	/Sample	$ 630	2
e	Water Analysis - VOCs (EPA Method 8260B)	7	$ 95	/Sample	$ 665	2
f	Water Analysis - pCBSA (Modified EPA Method 314.0)	7	$ 80	/Sample	$ 560	2
	Total Lab Analytical (Extraction Wells)				**$ 12,985**	

Appendix J
Table 5.2
Detailed Cost, Hydraulic Displacement
Well Construction

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
9		**Injection Wells (12" HSA Drilling to 100.5' bgs)**					
	a	HSA Drilling	100.5	$ 30	/Foot	$ 3,015	3
	b	Install 4-Inch Stainless Steel Wire Wrap Screen	40	$ 80	/Foot	$ 3,200	3
	c	Install 4-Inch LCS Casing	60	$ 20	/Foot	$ 1,200	3
	d	Bore hole materials (Cement, bentonite, sand, and concrete)	100.5	$ 12	/Foot	$ 1,206	3
	e	Forklift and Hopper Rental for Waste Handling	1	$ 250	/Day	$ 250	1
	f	Drill Crew per Diem	1	$ 450	/Night	$ 450	1
	g	Vehicle Usage	1	$ 100	/Day	$ 100	
	h	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
	i	Installation Permit	1	$ 201	/Each	$ 201	
	j	Other Direct Costs	1	$ 300	/Day	$ 300	
		Cost per Well				$ 10,422	
		Number of Wells (1 Well Installed per Day)				36	
		Subtotal - Injecton Wells				**$ 375,192**	
10		**Develop Extraction and Injection Wells**					
	a	Development Rig	1	$ 2,000	/Day	$ 2,000	1
	b	Development Crew per Diem	1	$ 200	/Night	$ 200	4
	c	Vehicle Usage	1	$ 100	/Day	$ 100	
	d	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
	e	Other Direct Costs	1	$ 300	/Day	$ 300	
		Cost per Well				$ 3,100	
		Number of Wells (1 Well Developed per Day)				65	
		Subtotal - Develop Extraction and Injection Wells				**$ 201,500**	
11		**BFS Monitoring Well Installation** (4 Days per Well for Installation and Development)	2	$ 54,000	/Well	**$ 108,000**	5

Appendix J
Table 5.2
Detailed Cost, Hydraulic Displacement
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
12	**Waste Management**					
a	Waste Tank Rental	168	$ 38	/Day	$ 6,384	6
b	Waste Tank Rental Delivery - Mob and Demob	1	$ 900	/Each	$ 900	6
c	Waste Bin Rental	540	$ 15	/Day	$ 8,100	6
d	Waste Bin Rental Delivery - Mob and Demob	18	$ 500	/Each	$ 9,000	6
e	Transport of Hazardous Soil Cuttings	18	$ 1,100	/Each	$ 19,800	6
f	Disposal of Hazardous Soil Cuttings	344	$ 550	/Ton	$ 189,472	6
g	Transport of Hazardous Water	5	$ 1,100	/Each	$ 5,500	6
h	Disposal of Hazardous Water	19700	$ 0.8	/Gal	$ 15,760	6
i	Waste Characterization/Profiling	2	$ 500	/Each	$ 1,000	
	Subtotal - Waste Management				**$ 255,916**	
	Total Subcontractor Cost w/10% Markup				**$ 1,489,204**	

TOTAL WELL CONSTRUCTION COST	**$ 1,911,079**

Cost Source Reference

1 Verbal Quote from Cascade Drilling
2 Verbal Quote from Test America
3 Water Development Corporation Quote Dated 10/09/08
4 Cascade Drilling Quote Dated July 15, 2008
5 Verbal Quote from Water Development Corporation
6 Verbal Quote from NRC Environmental

Appendix J
Table 5.3
Detailed Cost, Hydrualic Displacement
Well Field Equipment Installation

Item	Consultant Labor and Direct Costs	Quantity	Unit Cost			Cost	Cost Ref.
1	**Electrical Service Upgrade**	1	$	50,000	LS	$ 50,000	
2	**Extraction Well Assemblies**						
a	Well Head Assemblies	32	$	500	Each	$ 16,000	
b	Groundwater Extraction Pump (Electric Submersible)	32	$	578.06	Each	$ 18,498	1
c	Armored Electrical Cable	3200	$	4.89	Foot	$ 15,648	2
d	Teflon Discharge Tubing (5/8" OD)	6400	$	7.85	Foot	$ 50,240	2
e	DNAPL Extraction Pump (Pneumatic)	32	$	2,448.85	Each	$ 78,363	3
f	Downwell Air Supply Hose (3/8" OD Teflon)	3200	$	3.76	LF	$ 12,032	2
g	Downwell Air Exhaust Hose (1/2" OD Teflon)	3200	$	5.43	LF	$ 17,376	2
h	Static Pressure Gage	64	$	48	/Each	$ 3,072	4
i	Temperature Indicator	32	$	127	/Each	$ 4,064	4
j	Flow Sensor	32	$	121	/Each	$ 3,872	5
k	Differential Pressure Gage	32	$	315	/Each	$ 10,080	5
	Total Extraction Well Assemblies					**$ 229,245**	
3	**Injection Well Assemblies**						
a	Well Head Assemblies	37	$	300	Each	$ 11,100	
b	Static Pressure Gage	37	$	48	/Each	$ 1,776	4
c	Temperature Indicator	37	$	127	/Each	$ 4,699	4
d	Flow Sensor	37	$	121	/Each	$ 4,477	5
e	Differential Pressure Gage	37	$	315	/Each	$ 11,655	5
	Total Injection Well Assemblies					**$ 33,707**	
4	**Field Technician - Extraction and Injection Well Assembly Construction and Installation** (Consultant Labor - Not Subject to Markup)	552	$	75	Hour	**$ 41,400**	

Appendix J
Table 5.3
Detailed Cost, Hydrualic Displacement
Well Field Equipment Installation

Item	Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
5	**Groundwater and DNAPL Extraction Piping and Electrical (Installed)**					
a	4-Inch Carbon Steel Pipe and Fittings	220	$ 51.45	LF	$ 11,320	6
b	2-Inch Carbon Steel Pipe and Fittings	2448	$ 23.87	LF	$ 58,434	6
c	1.5-Inch Carbon Steel Pipe and Fittings	1345	$ 18.51	LF	$ 24,905	6
d	3.5-Inch Galvanized Steel Pipe	110	$ 33.42	LF	$ 3,676	6
e	3-Inch Galvanized Steel Pipe	1224	$ 27.05	LF	$ 33,113	6
f	2.5-Inch Galvanized Steel Pipe	673	$ 22.28	LF	$ 14,983	6
g	Electrical Wire	2007	$ 5.46	LF	$ 10,963	6
	Total Groundwater and DNAPL Extraction Piping and Electrical				$ 157,393	
6	**Injection Piping (Installed)**					
a	4-Inch Carbon Steel Pipe and Fittings	110	$ 51.45	LF	$ 5,660	6
b	2-Inch Carbon Steel Pipe and Fittings	1234	$ 23.87	LF	$ 29,456	6
c	1.5-Inch Carbon Steel Pipe and Fittings	745	$ 18.51	LF	$ 13,793	6
	Total Injection Piping				$ 48,909	
7	**Compressed Air Pipe and Fittings (2-Inch Carbon Steel) (Installed)**	2007	$ 23.87	LF	$ 47,899	6
8	**Pipe Supports**	209	$ 200	LF	$ 41,781	
	CONSULTANT LABOR COST				$ 41,400	
	DIRECT COSTS w/10% MARKUP				$ 669,828	
	TOTAL WELL FIELD EQUIPMENT INSTALLTION COST				$ 711,228	

Cost Source Reference

1 Shaw Pump and Supply, Inc. Quote Dated September 24, 2008
2 McMaster-Carr Catalog Price
3 QED Environmental Systems, Inc. Quote Dated September 25, 2008
4 Grainger Catalog Price
5 Dwyer Instruments, Inc. Catalog Price
6 Cost in 2008 dollars based on 2006 RS Means and an assumed inflation rate if 3% per year

Appendix J
Table 5.4
Detailed Cost, Hydraulic Displacement
DNAPL Collection Equipment Installation

Item	Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
1	240 Gallon Decanter	1	$ 3,344	/Each	$ 3,344	1
2	200 GPM DNAPL/Water Separator	1	$ 124,365	/Each	$ 124,365	2
3	Groundwater Holding Tank	1	$ 50,000	/Each	$ 50,000	
4	Dual Filter Bag System	1	$ 13,000	/Each	$ 13,000	3
5	Air Compressor (1004 CFM Rotary Screw)	1	$ 51,888	/Each	$ 51,888	4
6	500-Gallon Collection Tank	1	$ 2,078	/Each	$ 2,078	5
7	Transfer Pump (50 gpm)	3	$ 536	/Each	$ 1,607	6
8	Transfer Pump (200 gpm)	1	$ 1,773	/Each	$ 1,773	6
9	Collection Plant Pad and Building	1	$ 106,750	/LS	$ 106,750	7
10	Subcontractor Installation Cost	1	$ 75,000	/LS	$ 75,000	
	TOTAL TREATMENT EQUIPMENT INSTALLATION COST w/10% MARKUP				**$ 472,785**	

Cost Source Reference

1 Highland Tank and Manufacturing Co. Quote Dated September 26, 2008
2 Pan America Environmental Quote Dated July 18, 2008
3 Verbal Quote from BakerCorp
4 Ingersoll Rand Quote Dated September 25, 2008
5 Harrington Plastic Catalog Price
6 Grainger Catalog Price
7 Assumed to be 30% less than treatment plant pad and building for groundwater treatment

Appendix J
Table 5.5
Detailed Cost, Hydraulic Displacement
Construction Management

Item	Consultant Labor	Quantity	Unit Cost			Cost
1	Project Manager	190	$	150	/Hour	$ 28,500
2	Senior Engineer/Geologist	190	$	125	/Hour	$ 23,750
3	Mid-Level Engineer/Geologist	185	$	100	/Hour	$ 18,500
4	Junior/Field Engineer/Geologist	750	$	75	/Hour	$ 56,250
5	Field Technician	750	$	75	/Hour	$ 56,250
6	Clerical/Drafting	100	$	50	/Hour	$ 5,000
	TOTAL CONSTRUCTION MANAGEMENT COST					**$ 188,250**

Appendix J
Table 5.6
Detailed Cost, Hydraulic Displacement
Annual Operations and Maintenance

Item	Consultant Labor (Operations)	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	156	$ 150	/Hour	$ 23,400	
2	Senior Engineer/Geologist	156	$ 125	/Hour	$ 19,500	
3	Mid-Level Engineer/Geologist	208	$ 100	/Hour	$ 20,800	
4	Junior/Field Engineer/Geologist (One Full Time Junior Engineer)	1,040	$ 75	/Hour	$ 78,000	
5	Field Technician (1.5 Full Time Equivalents)	2,080	$ 75	/Hour	$ 156,000	
6	Clerical/Drafting	0	$ 50	/Hour	$ -	
	Consultant Labor Cost for Operations				**$ 297,700**	

Item	Consultant Labor (Reporting, H&S, Data Mngt, and Website Maintenance	Quantity	Unit Cost		Cost	Cost Ref.
7	Project Manager	20	$ 150	/Hour	$ 3,000	
8	Senior Engineer/Geologist	80	$ 125	/Hour	$ 10,000	
9	Mid-Level Engineer/Geologist	130	$ 100	/Hour	$ 13,000	
10	Junior/Field Engineer/Geologist	520	$ 75	/Hour	$ 39,000	
11	Field Technician	0	$ 75	/Hour	$ -	
12	Clerical/Drafting	240	$ 50	/Hour	$ 12,000	
	Consultant labor for Reporting, H&S, Data Mngt, and Website Maintenance				**$ 77,000**	

Appendix J
Table 5.6
Detailed Cost, Hydraulic Displacement
Annual Operations and Maintenance

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
13	**Waste Management**					
a	Filtration Generated Waste Disposal (Listed Waste for Incineration)	78,600	$ 0.25	/lb	$ 19,650	1
b	Filtration Generated Waste Transportation	4	$ 2,800	/Load	$ 11,200	1
	DNAPL T&D - Year 1					
	Tank Loads					
c	Transportation	4	$ 3,650	/Load	$ 14,600	1
d	Disposal	126,746	$ 0.50	/lb	$ 63,373	1
	DNAPL T&D - Year 2					
	Tank Loads					
e	Transportation	4	$ 3,650	/Load	$ 14,600	1
f	Disposal	45,908	$ 0.50	/lb	$ 22,954	1
	DNAPL T&D - Year 3					
	55-Gallon Drums					
g	Transportation and Disposal	26	$ 612	/drum	$ 15,901	2
	DNAPL T&D - Year 4					
	55-Gallon Drums					
h	Transportation and Disposal	16	$ 612	/drum	$ 9,785	2
	DNAPL T&D - Year 5					
	55-Gallon Drums					
i	Transportation and Disposal	5	$ 612	/drum	$ 3,058	2
	Total Waste Management - Year 1				**$ 108,823**	
	Total Waste Management - Year 2				**$ 68,404**	
	Total Waste Management - Year 3				**$ 46,751**	
	Total Waste Management - Year 4				**$ 40,635**	
	Total Waste Management - Year 5				**$ 33,908**	

Appendix J
Table 5.6
Detailed Cost, Hydraulic Displacement
Annual Operations and Maintenance

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
14		**Lab Analytical and Monitoring**					
	c	Water Analysis - Pesticides (EPA Method 8081A)	152	$ 90	/Each	$ 13,680	3
	d	Water Analysis - VOCs (EPA Method 8260B)	152	$ 95	/Each	$ 14,440	3
	e	Water Analysis - pCBSA (Modifed EPA Method 314.0)	152	$ 80	/Each	$ 12,160	3
		Total Lab Analytical and Monitoring				**$ 40,280**	
15		**Miscellaneous - Year 1**					
	a	Temporary Office 24'x60' Delivery and Setup	1	$ 2,939	/Each	$ 2,939	4
	b	Temporary Office 24'x60' Rental	12	$ 1,030	/Month	$ 12,356	4
	c	Temporary Office 24'x60' Demobilization	0	$ 1,746	/Each	$ -	4
	d	Temporary Storage Trailer	12	$ 149	/Month	$ 1,784	5
	e	Portable Toilet Delivery	1	$ 22	/Each	$ 22	6
	f	Portable Toilet Rental	12	$ 76	/Month	$ 908	6
	g	Well and Pump Maintenance Parts	12	$ 8,235	/Month	$ 98,824	
	h	Fed Ex and Deliveries	52	$ 100	/Week	$ 5,200	
	i	Temporary office comm. (internet, telephone, fax)	12	$ 1,000	/Month	$ 12,000	
	j	Operator Truck Usage (One Truck per Operator)	260	$ 100	/Day/Truck	$ 26,000	
		Total Miscellaneous - Year 1				**$ 160,032**	

Appendix J
Table 5.6
Detailed Cost, Hydraulic Displacement
Annual Operations and Maintenance

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
16		**Miscellaneous - Years 2 through 4**					
	a	Temporary Office 24'x60' Delivery and Setup	0	$ 2,939	/Each	$ -	4
	b	Temporary Office 24'x60' Rental	12	$ 1,030	/Month	$ 12,356	4
	c	Temporary Office 24'x60' Demobilization	0	$ 1,746	/Each	$ -	4
	d	Temporary Storage Trailer	12	$ 149	/Month	$ 1,784	5
	e	Portable Toilet Delivery	0	$ 22	/Each	$ -	6
	f	Portable Toilet Rental	12	$ 76	/Month	$ 908	6
	g	Well and Pump Maintenance Parts	12	$ 8,235	/Month	$ 98,824	
	h	Fed Ex and Deliveries	52	$ 100	/Week	$ 5,200	
	i	Temporary office comm. (internet, telephone, fax)	12	$ 1,000	/Month	$ 12,000	
	j	Operator Truck Usage (One Truck per Operator)	260	$ 100	/Day/Truck	$ 26,000	
		Total Miscellaneous - Years 2 through 4				**$ 157,071**	
17		**Miscellaneous - Year 5**					
	a	Temporary Office 24'x60' Delivery and Setup	0	$ 2,939	/Each	$ -	4
	b	Temporary Office 24'x60' Rental	12	$ 1,030	/Month	$ 12,356	4
	c	Temporary Office 24'x60' Demobilization	1	$ 1,746	/Each	$ 1,746	4
	d	Temporary Storage Trailer	12	$ 149	/Month	$ 1,784	5
	e	Portable Toilet Delivery	0	$ 22	/Each	$ -	6
	f	Portable Toilet Rental	12	$ 76	/Month	$ 908	6
		Well and Pump Maintenance Parts	12	$ 8,235	/Month	$ 98,824	
		Fed Ex and Deliveries	52	$ 100	/Week	$ 5,200	
		Temporary office comm. (internet, telephone, fax)	12	$ 1,000	/Month	$ 12,000	
		Operator Truck Usage (One Truck per Operator)	260	$ 100	/Day/Truck	$ 26,000	
		Total Miscellaneous - Year 5				**$ 158,818**	

Appendix J
Table 5.6
Detailed Cost, Hydraulic Displacement
Annual Operations and Maintenance

	Total Subcontractor Cost - Year 1	$	309,135	
	Total Subcontractor Cost - Year 2	$	265,755	
	Total Subcontractor Cost - Year 3	$	244,103	
	Total Subcontractor Cost - Year 4	$	237,987	
	Total Subcontractor Cost - Year 5	$	233,006	

Item	Utilities	Quantity	Unit Cost			Cost		Cost Ref.
18	**Electricity Usage**							
a	HiPOx Sytem	0	$	0.1045	/kWh	$	-	7
b	Air Compressor and Pumps	873,961	$	0.1045	/kWh	$	91,329	7
	Total Utilities					$	91,329	

	CONSULTANT LABOR COST	$	374,700	
	SUBCONTRACTOR COST w/10% MARKUP - YEAR 1	$	340,048	
	SUBCONTRACTOR COST w/10% MARKUP - YEAR 2	$	292,331	
	SUBCONTRACTOR COST w/10% MARKUP - YEAR 3	$	268,513	
	SUBCONTRACTOR COST w/10% MARKUP - YEAR 4	$	261,785	
	SUBCONTRACTOR COST w/10% MARKUP - YEAR 5	$	256,306	
	UTILITIES COST (NO MARKUP)	$	91,329	

BOE-C6-0060174

Appendix J
Table 5.6
Detailed Cost, Hydraulic Displacement
Annual Operations and Maintenance

TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 1	**$**	**806,077**
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 2	**$**	**758,360**
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 3	**$**	**734,542**
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 4	**$**	**727,814**
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 5	**$**	**722,335**

Cost Source Reference

[1] Clean Harbors Quote Dated October 10, 2007
[2] Verbal Quote from Clean Harbors
[3] Verbal Quote from Test America
[4] Mobile Mini, Inc. Quote Dated October 11, 2007
[5] Verbal Quote from Mobile Mini, Inc.
[6] Verbal Quote from A-1 Coast Port-A-Toilet
[7] Shedule A-3 LADWP Rate (Second Quarter 2008)

Appendix J
Table 5.7
Detailed Cost, Hydraulic Displacement
Well Abandonment

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	35	$ 150	/Hour	$ 5,250	
2	Senior Engineer/Geologist	145	$ 125	/Hour	$ 18,125	
3	Mid-Level Engineer/Geologist	145	$ 100	/Hour	$ 14,500	
4	Junior/Field Engineer/Geologist	555	$ 75	/Hour	$ 41,625	
5	Field Technician	145	$ 75	/Hour	$ 10,875	
6	Clerical/Drafting	145	$ 50	/Hour	$ 7,250	
	Total Consultant Labor Cost				**$ 97,625**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
1	**Mobilization/Demobilization of Drill Rig**	1	$ 2,000	/LS	**$ 2,000**	1
2	**Abandon Extraction Wells**					
a	Drill out well materials	5	$ 65	/Foot	$ 325	1
b	Pressure grout well	105	$ 30	/Foot	$ 3,150	1
c	Forklift and mini-hopper	0.5	$ 500	/Day	$ 250	1
d	Abandonment Crew per Diem	0.5	$ 200	/Night	$ 100	1
e	Vehicle Usage	0.5	$ 100	/Day	$ 50	
f	Equipment Rental and Supplies	0.5	$ 150	/Day	$ 75	
g	Other Direct Costs	0.5	$ 150	/Day	$ 75	
	Cost per Well				$ 4,025	
	Number of Wells (2 Wells Abandoned per Day)				32	
	Total for Extraction Well Adandonment				**128,800**	

Appendix J
Table 5.7
Detailed Cost, Hydraulic Displacement
Well Abandonment

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
3	**Abandon Injection Wells**					
a	Drill out well materials	5	$ 65	/Foot	$ 325	1
b	Pressure grout well	100.5	$ 30	/Foot	$ 3,015	1
c	Forklift and mini-hopper	0.5	$ 500	/Day	$ 250	1
d	Abandonment Crew per Diem	0.5	$ 200	/Night	$ 100	1
e	Vehicle Usage	0.5	$ 100	/Day	$ 50	
f	Equipment Rental and Supplies	0.5	$ 150	/Day	$ 75	
g	Other Direct Costs	0.5	$ 150	/Day	$ 75	
	Cost per Well				$ 3,890	
	Number of Wells (2 Wells Abandoned per Day)				37	
	Total for Injection Well Abandonment				**143,930**	

Appendix J
Table 5.7
Detailed Cost, Hydraulic Displacement
Well Abandonment

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
8		**Waste Management**					
	a	Waste Tank Rental	65	$ 38	/Day	$ 2,451	2
	b	Waste Tank Rental Delivery - Mob and Demob	1	$ 900	/Each	$ 900	2
	c	Waste Bin Rental	194	$ 15	/Day	$ 2,903	2
	d	Waste Bin Rental Delivery - Mob and Demob	3	$ 500	/Each	$ 1,500	2
	e	Transport and Disposal/Recycling of Steel	1	$ 1,100	/Load	$ 1,100	
	f	Transport of Hazardous Soil Cuttings	2	$ 1,100	/Each	$ 2,200	2
	g	Disposal of Hazardous Soil Cuttings	23	$ 550	/Ton	$ 12,396	2
	h	Transport of Hazardous Water	2	$ 1,100	/Each	$ 2,200	2
	i	Disposal of Hazardous Water	6900	$ 0.8	/Gal	$ 5,520	2
	j	Waste Characterization/Profiling	2	$ 500	/Each	$ 1,000	
		Total Waste Management				**$ 32,169**	
		Total Subcontractor Cost w/10% Markup				**$ 337,589**	

TOTAL WELL ABANDONMENT COST	**$ 435,214**

Cost Source Reference

1 Verbal Quote from Water Development Corporation
2 Verbal Quote from NRC Environmental Services

Appendix J
Table 5.8
Detailed Cost, Hydraulic Displacement
Demobilization

Item	Consultant Labor	Quantity	Unit Cost			Cost	Cost Ref.
1	Project Manager	20	$	150	/Hour	$ 3,000	
2	Senior Engineer/Geologist	45	$	125	/Hour	$ 5,625	
3	Mid-Level Engineer/Geologist	120	$	100	/Hour	$ 12,000	
4	Junior/Field Engineer/Geologist	365	$	75	/Hour	$ 27,375	
5	Field Technician	145	$	75	/Hour	$ 10,875	
6	Clerical/Drafting	55	$	50	/Hour	$ 2,750	
	Consultant Labor Cost					**$ 61,625**	

Item	Subcontractor Cost	Quantity	Unit Cost			Cost	Cost Ref.
7	**Remove Purchased Treatment Equipment**	1	$	101,000	/LS	**$ 101,000**	
8	**Close-Out Borings**						
a	Drilling and backfilling (6-Inch Sonic to 105 feet bgs at $65/foot)	8	$	6,825	/Boring	$ 54,600	1
b	Disposal of Hazardous Soil Cuttings	9.9	$	550	/Ton	$ 5,440	2
c	Transportation of Hazardous Soil Cuttings	1	$	1,100	/Each	$ 1,100	2
d	Waste Bin Rental Delivery - Mob and Demob	1	$	500	/Each	$ 500	2
e	Waste Bin Rental	30	$	15	/Day	$ 450	2
f	Soil Pesticides (EPA Method 8081A)	48	$	90	/Sample	$ 4,320	3
g	Soil VOCs (EPA Method 8260B)	48	$	95	/Sample	$ 4,560	3
h	Soil pCBSA (Modified EPA Method 314.0)	48	$	80	/Sample	$ 3,840	3
i	Liquid Pesticides (EPA Method 8081A)	8	$	90	/Sample	$ 720	3
j	Liquid VOCs (EPA Method 8260B)	8	$	95	/Sample	$ 760	3
k	Liquid pCBSA (Modified EPA Method 314.0)	8	$	80	/Sample	$ 640	3
	Total for Close-Out Borings					**$ 76,930**	
	Total Subcontractor Cost w/10% Markup					**$ 195,723**	

	TOTAL DEMOBILIZATION COST	**$ 257,348**

Cost Source Reference

1 Verbal Quote from Water Development Corporation
2 Verbal Quote from NRC Environmental Services
3 Verbal Quote from Test America

Appendix J
Table 6.0
Cost Summary
Unsaturated Zone SVE (Coupled with Thermal Remedy)

Discount Rate 4%

Year	Activity	Detailed Cost Table	Cost (Undiscounted)	Cost (NPV)
1	Design	J-6.1 Design	$ 94,359	$ 90,729
2	System Construction	J-6.2 Well Construction	$ 188,329	$ 447,218
		J-6.3 Well Field Equipment Installation	$ 60,013	
		J-6.4 Treatment Equipment Installation	$ 189,831	
		J-6.5 Construction Management	$ 45,538	
3	Operation and Maintenance - Year 1	J-6.6 Annual O&M - Carbon Regen for Vapor Treatment	$ 449,164	$ 399,305
4	Operation and Maintenance - Year 2	J-6.7 Annual O&M - Disposable Carbon for Vapor Treatment	$ 653,591	$ 558,692
5	Operation and Maintenance - Year 3		$ 586,491	$ 482,053
6	Operation and Maintenance - Year 4		$ 539,411	$ 426,304
7	Verification and Abandonment	J-6.8 Well Abandonment	$ 60,764	$ 117,372
		J-6.9 Demobilization	$ 93,690	

Total NPV at 7 Years	$ 2,521,673
Total Undiscounted Cost	$ 2,961,178

Appendix J
Table 6.0
Cost Summary
Unsaturated Zone SVE (Coupled with Thermal Remedy)

Discount Rate 4%

Year	Activity	Detailed Cost Table	Cost (Undiscounted)	Cost (NPV)
1	Design	J-6.1 Design	$ 94,359	$ 90,729
2	System Construction	J-6.2 Well Construction	$ 188,329	$ 447,218
		J-6.3 Well Field Equipment Installation	$ 60,013	
		J-6.4 Treatment Equipment Installation	$ 189,831	
		J-6.5 Construction Management	$ 45,538	
3	Operation and Maintenance - Year 1	J-6.6 Annual O&M - Carbon Regen for Vapor Treatment	$ 449,164	$ 399,305
4	Operation and Maintenance - Year 2	J-6.7 Annual O&M - Disposable Carbon for Vapor Treatment	$ 653,591	$ 558,692
5	Operation and Maintenance - Year 3		$ 586,491	$ 482,053
6	Operation and Maintenance - Year 4		$ 539,411	$ 426,304
7	Verification and Abandonment	J-6.8 Well Abandonment	$ 60,764	$ 117,372
		J-6.9 Demobilization	$ 93,690	

Total NPV at 7 Years	$ 2,521,673
Total Undiscounted Cost	$ 2,961,178

Appendix J
Table 6.2
Detailed Cost, Unsaturated Zone SVE (Coupled with Thermal Remedy)
Well Construction

Item	Consultant Labor	Quantity	Unit Cost			Cost	Cost Ref.
1	Project Manager	24	$	150	/Hour	$ 3,600	
2	Senior Engineer/Geologist	24	$	125	/Hour	$ 3,000	
3	Mid-Level Engineer/Geologist	52	$	100	/Hour	$ 5,200	
4	Junior/Field Engineer/Geologist	120	$	75	/Hour	$ 9,000	
5	Field Technician	42	$	75	/Hour	$ 3,150	
6	Clerical/Drafting	24	$	50	/Hour	$ 1,200	
	Total Consultant Labor Cost					**$ 25,150**	

Item	Subcontractor Cost	Quantity	Unit Cost			Cost	Cost Ref.
7	**HSA Rig Mobilization**	1	$	1,200	/Each	**$ 1,200**	1
8	**Palos Verdes Sands SVE Wells (12" HSA Drilling to 45' bgs)**						
a	Install Well Constructed of 6" LCS Casing w/ 20' of SS Screen	1	$	8,500	/Each	$ 8,500	1
b	Forklift and Hopper Rental for Waste Handling	0.5	$	250	/Day	$ 125	1
c	Drill Crew per Diem	0.5	$	450	/Night	$ 225	1
d	Vehicle Usage	0.5	$	100	/Day	$ 50	
e	Equipment Rental and Supplies	0.5	$	500	/Day	$ 250	
f	Other Direct Costs	0.5	$	300	/Day	$ 150	
	Cost per Well					$ 9,300	
	Number of Wells (2 Wells Installed per Day)					7	
	Subtotal - PVS Wells					**$ 65,100**	

Appendix J
Table 6.2
Detailed Cost, Unsaturated Zone SVE (Coupled with Thermal Remedy)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost			Cost	Cost Ref.
9	**UBA SVE Wells (12" HSA Drilling to 60 bgs)**						
a	Install Well Constructed of 6" LCS Casing w/ 15' of SS Screen	1	$	9,700	/Each	$ 9,700	1
b	Forklift and Hopper Rental for Waste Handling	0.5	$	250	/Day	$ 125	1
c	Drill Crew per Diem	0.5	$	450	/Night	$ 225	1
d	Vehicle Usage	0.5	$	100	/Day	$ 50	
e	Equipment Rental and Supplies	0.5	$	500	/Day	$ 250	
f	Installation Permit	1	$	201	/Each	$ 201	
g	Other Direct Costs	0.5	$	300	/Day	$ 150	
	Cost per Well					$ 10,701	
	Number of Wells (2 Wells Installed per Day)					5	
	Subtotal - UBA Wells					**$ 53,505**	
10	**Lab Analytical (Three PVS Borinngs and Four UBA Borings)**						
a	Soil Analysis - Pesticides (EPA Method 8081A)	10	$	90	/Sample	$ 900	2
b	Soil Analysis - VOCs (EPA Method 8260B)	10	$	95	/Sample	$ 950	2
c	Soil Analysis - pCBSA (Modified EPA Method 314.0)	10	$	80	/Sample	$ 800	2
d	Water Analysis - Pesticides (EPA Method 8081A)	2	$	90	/Sample	$ 180	2
e	Water Analysis - VOCs (EPA Method 8260B)	2	$	95	/Sample	$ 190	2
f	Water Analysis - pCBSA (Modified EPA Method 314.0)	2	$	80	/Sample	$ 160	2
	Total Lab Analytical (Extraction Wells)					**$ 3,180**	

Appendix J
Table 6.2
Detailed Cost, Unsaturated Zone SVE (Coupled with Thermal Remedy)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost			Cost	Cost Ref.
11	**Waste Management**						
a	Waste Tank Rental	36	$	38	/Day	$ 1,368	3
b	Waste Tank Rental Delivery - Mob and Demob	1	$	900	/Each	$ 900	3
c	Waste Bin Rental	60	$	15	/Day	$ 900	3
d	Waste Bin Rental Delivery - Mob and Demob	2	$	500	/Each	$ 1,000	3
e	Transport of Hazardous Soil Cuttings	2	$	1,100	/Each	$ 2,200	3
f	Disposal of Hazardous Soil Cuttings	29	$	550	/Ton	$ 15,932	3
g	Transport of Hazardous Water	1	$	1,100	/Each	$ 1,100	3
h	Disposal of Hazardous Water	1200	$	0.8	/Gal	$ 960	3
i	Waste Characterization/Profiling	2	$	500	/Each	$ 1,000	
	Subtotal - Waste Management					**$ 25,360**	
	Total Subcontractor Cost w/10% Markup					**$ 163,179**	

TOTAL WELL CONSTRUCTION COST	**$ 188,329**

Cost Source Reference

1 Verbal Quote from Water Development Corporation
2 Verbal Quote from Test America
3 Verbal Quote from NRC Environmental

Appendix J
Table 6.3
Detailed Cost, Unsaturated Zone SVE (Coupled with Thermal Remedy)
Well Field Equipment Installation

Item	Consultant Labor and Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
1	**Extraction Well Assemblies**					
a	Static Pressure Gage	12	$ 48	/Each	$ 576	1
b	Temperature Indicator	12	$ 127	/Each	$ 1,524	1
c	Flow Sensor	12	$ 121	/Each	$ 1,452	2
d	Differential Pressure Gage	12	$ 315	/Each	$ 3,780	2
	Total Extraction Well Assemblies				$ 7,332	
3	**SVE Piping**					
a	8-Inch Carbon Steel Pipe and Fittings	320	$ 94.71	LF	$ 30,307	3
b	6-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	120	$ 67.65	LF	$ 8,118	3
	Total SVE Piping				$ 38,425	
4	**Pipe Supports**	44	$ 200	LF	$ 8,800	
	DIRECT COSTS w/10% MARKUP				$ 60,013	
	TOTAL WELL FIELD EQUIPMENT INSTALLTION COST				$ 60,013	

Cost Source Reference

1 Grainger Catalog Price
2 Dwyer Instruments, Inc. Catalog Price
3 Cost in 2008 dollars based on 2006 RS Means and an assumed inflation rate if 3% per year

Appendix J
Table 6.4
Detailed Cost, Unsaturated Zone SVE (Coupled with Thermal Remedy)
Treatment Equipment Installation

Item	Direct Costs	Quantity	Unit Cost			Cost		Cost Ref.
	Carbon Regen System Upgrade (from 5000-lb to vessels to 10000-lb vessels)	1	$	46,000	/LS	$	46,000	1
	Polishing Carbon Vessel Upgrade (from 5000-lb to 10000-lb)	2	$	16,000	/Each	$	32,000	2
	Additional Initial Carbon Fill (Virgin Coconut)	10,000	$	1.07	/lb	$	10,700	2
	Oriface Plate and Transmitter	1	$	10,000	/Each	$	10,000	
	Moister Separator	1	$	4,000	/Each	$	4,000	3
	Transfer Pump (50 gpm)	1	$	536	/Each	$	536	4
	1000 SCFM Positive Displacement Blower (for PVS)	1	$	30,000	/Each	$	30,000	5
	300 SCFM Liquid Ring Blower (Hi Vac for UBA)	0	$	45,980	/Each	$	-	5
	Inline Stack PID	0	$	3,775	/Each	$	-	6
	Static Pressure Gage	3	$	48	/Each	$	144	4
	Temperature Indicator	3	$	127	/Each	$	381	4
	Interconnecting Piping (10% of Blower, KO Tank, and Regen and Polishing Carbon Vessel Upgrade)	1	$	12,598	LS	$	12,598	
	Electrical Allowance (20% of elec components)	1	$	8,107	LS	$	8,107	
	Control System Allowance (20% of elec components)	1	$	8,107	LS	$	8,107	
	Treatment Plant Pad and Building	0	$	-	LS	$	-	7
	Subcontractor Installation Cost	1	$	10,000	LS	$	10,000	
	TOTAL TREATMENT EQUIPMENT INSTALLATION COST w/10% MARKUP					**$**	**189,831**	

Cost Source Reference

1 Based on MEGTEC Systems, Inc. Quote Dated April 20, 2008
2 Based on July 1 2008 BakerCorp Quote
3 Verbal Quote from Enviro Supply and Services
4 Grainger Catalog Price
5 Yardley Pump and Vacuum Quote Dated July 16, 2008
6 Verbal Quote from RAE Systems
7 Based on Building/Lab Site Improvements Cost for 350 gpm LGAC Adsorber System in 1998 Joint Groundwater Feasibility Study for the Montrose and Del Amo Sites

Appendix J
Table 6.5
Detailed Cost, Unsaturated Zone SVE (Coupled with Thermal Remedy)
Construction Management

Item	Consultant Labor	Quantity	Unit Cost			Cost
1	Project Manager	20	$	150	/Hour	$ 3,000
2	Senior Engineer/Geologist	45	$	125	/Hour	$ 5,625
3	Mid-Level Engineer/Geologist	90	$	100	/Hour	$ 8,978
4	Junior/Field Engineer/Geologist	180	$	75	/Hour	$ 13,467
5	Field Technician	180	$	75	/Hour	$ 13,467
6	Clerical/Drafting	20	$	50	/Hour	$ 1,000
	TOTAL CONSTRUCTION MANAGEMENT COST					$ 45,538

Appendix J
Table 6.6
Detailed Cost, Unsaturated Zone SVE (Coupled with Thermal Remedy)
Annual Operations and Maintenance (Year 1)

Item	Consultant Labor (Operations)	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	65	$ 150	/Hour	$ 9,750	
2	Senior Engineer/Geologist	65	$ 125	/Hour	$ 8,125	
3	Mid-Level Engineer/Geologist	130	$ 100	/Hour	$ 13,000	
4	Junior/Field Engineer/Geologist	260	$ 75	/Hour	$ 19,500	
5	Field Technician	0	$ 75	/Hour	$ -	
6	Clerical/Drafting	0	$ 50	/Hour	$ -	
	Consultant Labor Cost for Operations				**$ 50,375**	

Item	Consultant Labor (Reporting, H&S, and Data Mngt)	Quantity	Unit Cost		Cost	Cost Ref.
7	Project Manager	40	$ 150	/Hour	$ 6,000	
8	Senior Engineer/Geologist	80	$ 125	/Hour	$ 10,000	
9	Mid-Level Engineer/Geologist	160	$ 100	/Hour	$ 16,000	
10	Junior/Field Engineer/Geologist	160	$ 75	/Hour	$ 12,000	
11	Field Technician	0	$ 75	/Hour	$ -	
12	Clerical/Drafting	160	$ 50	/Hour	$ 8,000	
	Consultant labor for Reporting, H&S, Data Mngt, and Website Maintenance				**$ 52,000**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
13	**Waste Management**					
a	**Additional Polishing VGAC and regen system VGAC change-outs**	45,000	$ 1.53	/lb	$ 68,625	1
b	**Additional Carbon Regen System Solvent**					
i	Transportation	4	$ 3,650	/load	$ 14,600	2
ii	Disposal (Listed Waste for Incineration)	159,870	$ 0.5	/lb	$ 79,935	2
c	**Additional Boiler Water Pre-Treatment Brine and Blowdown**					
i	Transportation	7	$ 950	/10,000 gals	$ 6,650	3
ii	Disposal (non-Haz)	63,009	$ 0.14	/gal	$ 8,821	3
	Total Waste Management				**$ 178,631**	

Appendix J
Table 6.6
Detailed Cost, Unsaturated Zone SVE (Coupled with Thermal Remedy)
Annual Operations and Maintenance (Year 1)

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
14	**Lab Analytical and Monitoring**					
a	Summa Can Rental	48	$ 40	/Each	$ 1,920	4
b	Vapor VOCs Analysis (EPA TO-15)	48	$ 200	/Each	$ 9,600	4
c	Tedlar Bags	12	$ 10	/Each	$ 120	
	Total Lab Analytical and Monitoring				**$ 11,640**	
15	**Miscellaneous - Year 1**					
a	Miscellaneous Parts	12	$ 1,000	/Month	$ 12,000	
b	Fed Ex and Deliveries	12	$ 100	/Month	$ 1,200	
	Total Miscellaneous - Year 1				**$ 13,200**	
Item	**Direct Cost**	**Quantity**	**Unit Cost**		**Cost**	**Cost Ref.**
16	**Utilities**					
a	Natural Gas (additional Steam for Carbon Regen Unit)	77,740	$ 1.14	/therm	$ 88,624	5
b	Municipal Water (additional steam for Carbon Regen Unit)	750,528	$ 0.0029	/gal	$ 2,177	
c	Electricity - PD Vacuum Blower	489,925	$ 0.1045	/kWh	$ 51,197	6
	Total Utilities				**$ 141,997**	

CONSULTANT LABOR COST	**$ 102,375**	
SUBCONTRACTOR COST w/10% MARKUP - YEAR 1	**$ 204,791**	
UTILITIES COST (NO MARKUP)	**$ 141,997**	
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 1	**$ 449,164**	

Cost Source Reference
1 Based on carbon costs associated with the Montrose Henderson SVE System
2 Clean Harbors Quote Dated October 10, 2007
3 NRC Environmental Services, Inc. Email Quote Dated June 30, 2008
4 Verbal Quote from Calscience
5 GN-10, Tier III, SoCal Gas Co. Rate (Effective May 1, 2008)
6 Shedule A-3 LADWP Rate (Second Quarter 2008)

Appendix J
Table 6.7
Detailed Cost, Unsaturated Zone SVE (Coupled with Thermal Remedy)
Annual Operations and Maintenance (Years 2 through 4)

Item	Consultant Labor (Operations)	Quantity	Unit Cost			Cost		Cost Ref.
1	Project Manager	52	$	150	/Hour	$	7,800	
2	Senior Engineer/Geologist	52	$	125	/Hour	$	6,500	
3	Mid-Level Engineer/Geologist	208	$	100	/Hour	$	20,800	
4	Junior/Field Engineer/Geologist	520	$	75	/Hour	$	39,000	
5	Field Technician	1,040	$	75	/Hour	$	78,000	
6	Clerical/Drafting	0	$	50	/Hour	$	-	
	Consultant Labor Cost for Operations					**$**	**152,100**	

Item	Consultant Labor (Reporting, H&S, and Data Mngt)	Quantity	Unit Cost			Cost		Cost Ref.
7	Project Manager	40	$	150	/Hour	$	6,000	
8	Senior Engineer/Geologist	80	$	125	/Hour	$	10,000	
9	Mid-Level Engineer/Geologist	160	$	100	/Hour	$	16,000	
10	Junior/Field Engineer/Geologist	160	$	75	/Hour	$	12,000	
11	Field Technician	0	$	75	/Hour	$	-	
12	Clerical/Drafting	160	$	50	/Hour	$	8,000	
	Consultant labor for Reporting, H&S, Data Mngt, and Website Maintenance					**$**	**52,000**	

Appendix J
Table 6.7
Detailed Cost, Unsaturated Zone SVE (Coupled with Thermal Remedy)
Annual Operations and Maintenance (Years 2 through 4)

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
13	**Turnkey VGAC Change-Out Service (incl. fresh VGAC and T&D of spent VGAC as Haz)**					
a	Year 2	140,000	$ 1.53	/lb VGAC	$ 213,500	1
b	Year 3	100,000	$ 1.53	/lb VGAC	$ 152,500	1
c	Year 4	60,000	$ 1.53	/lb VGAC	$ 91,500	1
14	**Final Spent VGAC (40,000 lbs) Transportation and Disposal**	40,000	$ 0.46	/lb VGAC	$ 18,200	1
	Total VGAC (Year 2)				**$ 213,500**	
	Total VGAC (Year 3)				**$ 152,500**	
	Total VGAC (Year 4)				**$ 109,700**	
15	**Lab Analytical and Monitoring**					
a	Summa Can Rental	84	$ 40	/Each	$ 3,360	2
b	Vapor VOCs Analysis (EPA TO-15)	84	$ 200	/Each	$ 16,800	2
c	Tedlar Bags	12	$ 10	/Each	$ 120	
	Total Lab Analytical and Monitoring				**$ 20,280**	

Appendix J
Table 6.7
Detailed Cost, Unsaturated Zone SVE (Coupled with Thermal Remedy)
Annual Operations and Maintenance (Years 2 through 4)

Item		Subcontractor Cost	Quantity	Unit Cost			Cost	Cost Ref.
16		**Miscellaneous - Years 2 through 4**						
	a	Temporary Office 24'x60' Rental	12	$	1,030	/Month	$ 12,356	3
	b	Temporary Storage Trailer	12	$	149	/Month	$ 1,784	4
	c	Portable Toilet Rental	12	$	76	/Month	$ 908	5
	d	Miscellaneous Parts	12	$	1,000	/Month	$ 12,000	
	e	Fed Ex and Deliveries	12	$	100	/Month	$ 1,200	
	f	Temporary office comm. (internet, telephone, fax)	12	$	1,000	/Month	$ 12,000	
	g	Operator Truck Usage (One Truck per Operator)	260	$	100	/Day/Truck	$ 26,000	
		Total Miscellaneous - Years 2 through 4					**$ 66,248**	
		Total Subcontractor Cost - Year 2					**$ 300,028**	
		Total Subcontractor Cost - Year 3					**$ 239,028**	
		Total Subcontractor Cost - Year 4					**$ 196,228**	

Item	Utilities	Quantity	Unit Cost			Cost	Cost Ref.
17	**Utilities**						
	Electricity - PD and Liquid Ring Vacuum Blowers	1,143,158	$	0.1045	/kWh	$ 119,460	6
	Total Utilities					**$ 119,460**	

CONSULTANT LABOR COST	$	**204,100**
SUBCONTRACTOR COST w/10% MARKUP - YEAR 2	$	**330,031**
SUBCONTRACTOR COST w/10% MARKUP - YEAR 3	$	**262,931**
SUBCONTRACTOR COST w/10% MARKUP - YEAR 4	$	**215,851**
UTILITIES COST (NO MARKUP)	$	**119,460**
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 2	$	**653,591**
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 3	$	**586,491**
TOTAL OPERATIONS AND MAINTENANCE COST - YEAR 4	$	**539,411**

Cost Source Reference

1 Based on carbon costs associated with the Montrose Henderson SVE System
2 Verbal Quote from Calscience
3 Mobile Mini, Inc. Quote Dated October 11, 2007
4 Verbal Quote from Mobile Mini, Inc.
5 Verbal Quote from A-1 Coast Port-A-Toilet
6 Shedule A-3 LADWP Rate (Second Quarter 2008)

Appendix J
Table 6.8
Detailed Cost, Unsatuared Zone SVE (Coupled with Thermal Remedy)
Well Abandonment

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	10	$ 150	/Hour	$ 1,500	
2	Senior Engineer/Geologist	20	$ 125	/Hour	$ 2,500	
3	Mid-Level Engineer/Geologist	20	$ 100	/Hour	$ 2,000	
4	Junior/Field Engineer/Geologist	80	$ 75	/Hour	$ 6,000	
5	Field Technician	20	$ 75	/Hour	$ 1,500	
6	Clerical/Drafting	20	$ 50	/Hour	$ 1,000	
	Total Consultant Labor Cost				**$ 14,500**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Mobilization/Demobilization of Drill Rig**	1	$ 2,000	/LS	**$ 2,000**	1
8	**Abandon PVS SVE Wells**					
a	Drill out well materials	5	$ 65	/Foot	$ 325	1
b	Pressure grout well	45	$ 30	/Foot	$ 1,350	1
c	Forklift and mini-hopper	0.5	$ 500	/Day	$ 250	1
d	Abandonment Crew per Diem	0.5	$ 200	/Night	$ 100	1
e	Vehicle Usage	0.5	$ 100	/Day	$ 50	
f	Equipment Rental and Supplies	0.5	$ 150	/Day	$ 75	
g	Other Direct Costs	0.5	$ 150	/Day	$ 75	
	Cost per Well				$ 2,225	
	Number of Wells (2 Wells Abandoned per Day)				7	
	Total for Extraction Well Adandonment				**15,575**	

Appendix J
Table 6.8
Detailed Cost, Unsatuared Zone SVE (Coupled with Thermal Remedy)
Well Abandonment

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
9	**Abandon UBA SVE Wells**					
a	Drill out well materials	5	$ 65	/Foot	$ 325	1
b	Pressure grout well	60	$ 30	/Foot	$ 1,800	1
c	Forklift and mini-hopper	0.5	$ 500	/Day	$ 250	1
d	Abandonment Crew per Diem	0.5	$ 200	/Night	$ 100	1
e	Vehicle Usage	0.5	$ 100	/Day	$ 50	
f	Equipment Rental and Supplies	0.5	$ 150	/Day	$ 75	
g	Other Direct Costs	0.5	$ 150	/Day	$ 75	
	Cost per Well				$ 2,675	
	Number of Wells (2 Wells Abandoned per Day)				5	
	Total for Injection Well Abandonment				**13,375**	
Item	**Subcontractor Cost**	**Quantity**	**Unit Cost**		**Cost**	**Cost Ref.**
10	**Waste Management**					
a	Waste Tank Rental	36	$ 38	/Day	$ 1,368	2
b	Waste Tank Rental Delivery - Mob and Demob	1	$ 900	/Each	$ 900	2
c	Waste Bin Rental	36	$ 15	/Day	$ 540	2
d	Waste Bin Rental Delivery - Mob and Demob	2	$ 500	/Each	$ 1,000	2
e	Transport and Disposal/Recycling of Steel	1	$ 1,100	/Load	$ 1,100	
f	Transport of Hazardous Soil Cuttings	1	$ 1,100	/Each	$ 1,100	2
g	Disposal of Hazardous Soil Cuttings	3.71	$ 550	/Ton	$ 2,040	2
h	Transport of Hazardous Water	1	$ 1,100	/Each	$ 1,100	2
i	Disposal of Hazardous Water	1200	$ 0.8	/Gal	$ 960	2
j	Waste Characterization/Profiling	2	$ 500	/Each	$ 1,000	
	Total Waste Management				**$ 11,108**	
	Total Subcontractor Cost w/10% Markup				**$ 46,264**	

	TOTAL WELL ABANDONMENT COST	$ 60,764

Cost Source Reference

1 Verbal Quote from Water Development Corporation
2 Verbal Quote from NRC Environmental Services

Appendix J
Table 6.9
Detailed Cost, Unsaturated Zone SVE (Coupled with Thermal Remedy)
Demobilization

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	8	$ 150	/Hour	$ 1,200	
2	Senior Engineer/Geologist	20	$ 125	/Hour	$ 2,500	
3	Mid-Level Engineer/Geologist	40	$ 100	/Hour	$ 4,000	
4	Junior/Field Engineer/Geologist	120	$ 75	/Hour	$ 9,000	
5	Field Technician	50	$ 75	/Hour	$ 3,750	
6	Clerical/Drafting	20	$ 50	/Hour	$ 1,000	
	Consultant Labor Cost				$ 21,450	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Remove Purchased Treatment Equipment**	1	41,000	/LS	$ 41,000	
8	**Demob Office Trailer**	1	$ 1,746	LS	$ 1,746	1
9	**Close-Out Borings**					
a	Drilling and backfilling (6-Inch Sonic to 45 feet bgs at $65/foot)	3	$ 2,925	/Boring	$ 8,775	2
b	Drilling and backfilling (6-Inch Sonic to 60 feet bgs at $65/foot)	2	$ 3,900	/Boring	$ 7,800	2
c	Disposal of Hazardous Soil Cuttings	3.0	$ 550	/Ton	$ 1,651	3
d	Transportation of Hazardous Soil Cuttings	1	$ 1,100	/Each	$ 1,100	3
e	Waste Bin Rental Delivery - Mob and Demob	1	$ 500	/Each	$ 500	3
f	Waste Bin Rental	30	$ 15	/Day	$ 450	3
g	Soil Pesticides (EPA Method 8081A)	10	$ 90	/Sample	$ 900	4
h	Soil VOCs (EPA Method 8260B)	10	$ 95	/Sample	$ 950	4
i	Soil pCBSA (Modified EPA Method 314.0)	10	$ 80	/Sample	$ 800	4
	Total for Close-Out Borings				$ 22,926	
	Total Subcontractor Cost w/10% Markup				$ 72,240	

TOTAL DEMOBILIZATION COST	$	93,690

Cost Source Reference

1 Mobile Mini, Inc. Quote Dated October 11, 2007
2 Water Development Corporation Quote Dated 10/09/08
3 Verbal Quote from NRC Environmental Services
4 Verbal Quote from Test America

Appendix J
Table 7.0
Cost Summary
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Focused Treatment Area

Discount Rate 4%

Year	Activity	Detailed Cost Table	Cost (Undiscounted)	Cost (NPV)
1	Focused Treatment Design	J-7.1 Design and Permitting	$ 1,293,125	$ 1,243,389
2	Focused Treatment Build	J-7.2 Well Construction	$ 5,374,953	$ 10,788,157
		J-7.3 Well Field Equipment Installation	$ 1,736,164	
		J-7.4 Instrumentation and Controls Installation	$ 271,275	
		J-7.5 Treatment Equipment Installation	$ 3,431,854	
		J-7.6 Construction Management	$ 327,250	
		J-7.7 Hot Floor Pre-Heat	$ 526,975	
3	Focused Treatment Operation and Maintenance	J-7.8 Operations and Maintenance	$ 8,158,628	$ 7,252,990
4	Verification and Abandonment	J-7.9 Well Abandonment	$ 1,021,037	$ 1,504,136
		J-7.10 Demobilization	$ 738,590	

Total NPV at 4 Years	$ 20,788,672
Total Undiscounted Cost	$ 22,879,849

Appendix J
Table 7.1
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Design and Permitting

Item	Consultant Labor	Quantity	Unit Cost		Cost
1	Project Manager	890	$ 150	/Hour	$ 133,500
2	Senior Engineer/Geologist	1,320	$ 125	/Hour	$ 165,000
3	Mid-Level Engineer/Geologist	5,200	$ 100	/Hour	$ 520,000
4	Junior/Field Engineer/Geologist	3,735	$ 75	/Hour	$ 280,125
5	Field Technician	0	$ 75	/Hour	$ -
6	Clerical/Drafting	1,250	$ 50	/Hour	$ 62,500
	Consultant Labor				**$ 1,161,125**

Item	Subcontractor Cost	Quantity	Unit Cost		Cost
7	**Outside Thermal Expert**	1	$ 120,000	/LS	**$ 120,000**
	Subcontractor Cost w/10% Markup				**$ 132,000**

TOTAL DESIGN AND PERMITTING COST	**$ 1,293,125**

Appendix J
Table 7.2
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Well Construction

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	560	$ 150	/Hour	$ 84,000	
2	Senior Engineer/Geologist	560	$ 125	/Hour	$ 70,000	
3	Mid-Level Engineer/Geologist	2,234	$ 100	/Hour	$ 223,400	
4	Junior/Field Engineer/Geologist	3,432	$ 75	/Hour	$ 257,400	
5	Field Technician	540	$ 75	/Hour	$ 40,500	
6	Clerical/Drafting	560	$ 50	/Hour	$ 28,000	
	Total Consultant Labor Cost				**$ 703,300**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Abandon Existing Site Wells Prior to Thermal Treatment**					
a	Drill out well materials	90	$ 65	/Foot	$ 5,850	1
b	Grout resulting boring	90	$ 30	/Foot	$ 2,700	1
c	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
d	Excavate and remove well box	1	$ 2,000	/LS	$ 2,000	1
e	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
f	Vehicle Usage	1	$ 100	/Day	$ 100	
g	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
h	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 11,650	
	Number of Wells				5	
	Total for Existing Site Well Abandonment				**$ 58,250**	

Appendix J
Table 7.2
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
8	**UBA Multi-Phase Extraction Wells (12" HSA Drilling to 108' bgs)**					
a	Install Well Constructed of 6" LCS Casing w/ 60' of SS Screen and 3-foot Sump, Type II Cement Grout, and Sand Pack	1	$ 12,000	/Each	$ 12,000	2
b	Forklift and Hopper Rental for Waste Handling	1	$ 250	/Day	$ 250	2
c	Drill Crew per Diem	1	$ 450	/Night	$ 450	2
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
f	Other Direct Costs	1	$ 300	/Day	$ 300	
	Cost per Well				$ 13,600	
	Number of Wells (1 Well Installed per Day)				27	
	Subtotal - UBA Multi-Phase Extraction Wells				**$ 367,200**	
9	**Lab Analytical (Sixteen UBA Multi-Phase Extraction Well Borings)**					
a	Soil Analysis - Pesticides (EPA Method 8081A)	54	$ 90	/Sample	$ 4,860	3
b	Soil Analysis - VOCs (EPA Method 8260B)	54	$ 95	/Sample	$ 5,130	3
c	Soil Analysis - pCBSA (Modified EPA Method 314.0)	54	$ 80	/Sample	$ 4,320	3
d	Water Analysis - Pesticides (EPA Method 8081A)	9	$ 90	/Sample	$ 810	3
e	Water Analysis - VOCs (EPA Method 8260B)	9	$ 95	/Sample	$ 855	3
f	Water Analysis - pCBSA (Modified EPA Method 314.0)	9	$ 80	/Sample	$ 720	3
	Total Lab Analytical (UBA Extraction Wells)				**$ 16,695**	

Appendix J
Table 7.2
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
10	**Triple-Nested UBA Steam Injecton Wells (12" HSA Drilling to 105' bgs)**					
a	Install and Well Constructed of Three 2" LCS Casings each w/ 5' of SS Screen, Type II Cement Grout, and Sand Pack. Total casing depths are 75, 90, and 105' bgs	1	$ 7,000	/Each	$ 7,000	2
b	Forklift and Hopper Rental for Waste Handling	1	$ 250	/Day	$ 250	2
c	Drill Crew per Diem	1	$ 450	/Night	$ 450	2
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
f	Other Direct Costs	1	$ 300	/Day	$ 300	
	Cost per Well				$ 8,600	
	Number of Wells (1 Well Installed per Day)				14	
	Subtotal - Triple-Nested UBA Steam Injecton Wells				**$ 120,400**	
11	**Develop UBA Multi-Phase Extraction Wells and Triple-Nested UBA Steam Injection Wells**					
a	Development Rig	1	$ 2,000	/Day	$ 2,000	2
b	Development Crew per Diem	1	$ 200	/Night	$ 200	2
	Cost per Well				$ 2,200	
	Number of Wells (1 Well Developed per Day)				41	
	Subtotal - Develop UBA Wells				**$ 90,200**	

Appendix J
Table 7.2
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
12	**Mobilization/Demobilization of Mud Rotary Drill Rig**	2	$ 12,000	/Each	**$ 24,000**	4
13	**Hot Floor Multi-Phase Extraction Wells**					
a	Move Between Well Locations	1	$ 2,000	/Each	$ 2,000	4
b	Install 14", .25" Wall, Low Carbon Steel Conductor Casing with Type II Cement Grout	110	$ 220	/Foot	$ 24,200	4
c	Mud Change-Out and Pit Decon	1	$ 2,000	/Each	$ 2,000	4
d	12" Boring Under Conductor	8.5	$ 80	/Foot	$ 680	4
e	Install 6" Low Carbon Steel Sched. 40 Casing	110.5	$ 88	/Foot	$ 9,724	4
f	Install 6" Type 304 Stainless Steel Screen with 3' Sump	8	$ 175	/Foot	$ 1,400	4
g	Type II Cement Grout and Sand Pack	118.5	$ 30	/Foot	$ 3,555	4
h	Forklift and Hopper Rental for Waste Handling	4	$ 400	/Day	$ 1,600	4
i	Standby for Cement Curing	6	$ 550	/Hour	$ 3,300	4
j	Well Development	10	$ 165	/Hour	$ 1,650	4
k	Vehicle Usage	4	$ 100	/Day	$ 400	
l	Equipment Rental and Supplies	4	$ 500	/Day	$ 2,000	
m	Other Direct Costs	4	$ 300	/Day	$ 1,200	
	Cost per Well				$ 53,709	
	Number of Wells (4 Days per Well for Installation and Development)				10	
	Subtotal - Hot Floor Multi-Phase Extraction Wells				**$ 537,090**	

Appendix J
Table 7.2
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
14	**Hot Floor Steam Injecton Wells**					
a	Move Between Well Locations	1	$ 2,000	/Each	$ 2,000	4
b	Install 10", .25" Wall, Low Carbon Steel Conductor Casing with Type II Cement Grout	110	$ 180	/Foot	$ 19,800	4
c	Mud Change-Out	1	$ 1,500	/Each	$ 1,500	4
d	9" Boring Under Conductor	5.5	$ 75	/Foot	$ 413	4
e	Install 2" Low Carbon Steel Sched. 40 Casing	110.5	$ 45	/Foot	$ 4,973	4
f	Install 2" Type 304 Stainless Steel Screen	5	$ 90	/Foot	$ 450	4
g	Type II Cement Grout and Sand Pack	115.5	$ 20	/Foot	$ 2,310	4
h	Forklift and Hopper Rental for Waste Handling	4	$ 400	/Day	$ 1,600	4
i	Standby for Cement Curing	5	$ 550	/Hour	$ 2,750	4
j	Well Development	6	$ 165	/Hour	$ 990	4
k	Vehicle Usage	4	$ 100	/Day	$ 400	
l	Equipment Rental and Supplies	4	$ 500	/Day	$ 2,000	
m	Other Direct Costs	4	$ 300	/Day	$ 1,200	
	Cost per Well				$ 40,385	
	Number of Wells (4 Days per Well for Installation and Development)				26	
	Subtotal - Hot Floor Steam Injecton Wells				**$ 1,050,010**	
15	**Temperature Monitoring Points**					
a	Move Between Well Locations	1	$ 2,000	/Each	$ 2,000	4
b	Install 10", .25 Wall, Low Carbon Steel Conductor Casing with Type II Cement Grout	110	$ 180	/Foot	$ 19,800	4
c	Mud Change-Out	1	$ 1,500	/Each	$ 1,500	4
d	8" Boring Under Conductor	5	$ 75	/Foot	$ 375	4
e	Install 1.5" Low Carbon Steel Casing with Bottom Cap	115	$ 40	/Foot	$ 4,600	4
f	Type II Cement Grout	115	$ 20	/Foot	$ 2,300	4
g	Forklift and Hopper Rental for Waste Handling	5	$ 400	/Day	$ 2,000	4
h	Standby for Cement Curing	5	$ 550	/Hour	$ 2,750	4
i	Vehicle Usage	5	$ 100	/Day	$ 500	4
j	Equipment Rental and Supplies	5	$ 500	/Day	$ 2,500	
k	Other Direct Costs	5	$ 300	/Day	$ 1,500	
	Subtotal				$ 39,825	
	Number of Wells (3 Days per Point - no Development Needed)				14	
	Subtotal - Temperature Monitoring Points				**$ 557,550**	

Appendix J
Table 7.2
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
16	**BFS Monitoring Well Installation** (4 Days per Well for Installation and Development)	2	$ 54,000	/Well	**$ 108,000**	1
17	**Waste Management**					
a	Waste Tank Rental	2920	$ 38	/Day	$ 110,960	5
b	Waste Tank Rental Delivery - Mob and Demob	8	$ 900	/Each	$ 7,200	5
c	Waste Bin Rental	1710	$ 15	/Day	$ 25,650	5
d	Waste Bin Rental Delivery - Mob and Demob	57	$ 500	/Each	$ 28,500	5
e	Transport of Hazardous Soil Cuttings	57	$ 1,100	/Each	$ 62,700	5
f	Disposal of Hazardous Soil Cuttings	1134	$ 550	/Ton	$ 623,700	5
g	Transport of Hazardous Mud	87	$ 500	/Each	$ 43,500	5
h	Disposal of Hazardous Mud	322717	$ 1.1	/Gal	$ 354,989	5
i	Transport of Hazardous Water	15	$ 1,100	/Each	$ 16,500	5
j	Disposal of Hazardous Water	52954	$ 0.8	/Gal	$ 42,363	5
k	Waste Characterization/Profiling	3	$ 500	/Each	$ 1,500	
	Subtotal - Waste Management				**$ 1,317,562**	
	Total Subcontractor Cost w/10% Markup				**$ 4,671,653**	

TOTAL WELL CONSTRUCTION COST	**$ 5,374,953**

Cost Source Reference

1 Verbal Quote from Water Development Corporation
2 Cascade Drilling, Inc. Quote Dated 7/15/08
3 Verbal Quote from Test America
4 Water Development Corporation Quote Dated 4/25/08
5 Verbal Quote from NRC Environmental

Appendix J
Table 7.3
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Well Field Equipment Installation

Item	Consultant Labor and Direct Costs	Quantity	Unit Cost			Cost		Cost Ref.
1	**Electrical Service Upgrade**	1	$	50,000	LS	$	50,000	
2	**Natural Gas Pipeline**	1	$	200,000	LS	$	200,000	
3	**Groundwater Extraction Assemblies**							
a	Well Head Assemblies	37	$	1,000	Each	$	37,000	
b	Extraction Pump (High Temperature Hammerhead Pro)	37	$	3,070	Each	$	113,590	1
c	Downwell Air Supply Hose (3/8" SS Brainded, Teflon Lined)	3700	$	11	LF	$	40,700	1
d	Downwell Air Exhaust Hose (1/2" SS Brainded, Teflon Lined)	3700	$	16	LF	$	59,200	1
e	Downwell Discharge Hose (1/4" SS Brainded, Teflon Lined)	3700	$	22	LF	$	81,400	1
	Total Groundwater Extraction Assemblies					$	331,890	
4	**Steam Injection Well Head Assemblies**	46	$	7,000	Each	$	322,000	
5	**Field Technician - Pump and Well Head Assembly Construction and Installation**							
	(Consultant Labor - Not Subject to Markup)	990	$	75	Hour	$	74,250	
6	**Steam Injection Piping**							
a	6-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	570	$	67.65	LF	$	38,561	2
b	4-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1140	$	43.45	LF	$	49,533	2
c	2-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1190	$	34.10	LF	$	40,579	2
	Total Steam Injection Piping					$	128,673	
7	**Vapor Extraction Piping**							
a	8-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	570	$	94.71	LF	$	53,985	3
b	6-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1140	$	67.65	LF	$	77,121	2
c	4-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1120	$	43.45	LF	$	48,664	2
	Total Vapor Extraction Piping					$	179,770	

Appendix J
Table 7.3
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Well Field Equipment Installation

Item	Consultant Labor and Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
8	**Groundwater Extraction Piping**					
a	4-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	560	$ 43.45	LF	$ 24,332	2
b	2-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1140	$ 34.10	LF	$ 38,874	2
c	1.5-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1120	$ 31.45	LF	$ 35,224	2
d	Total Piping Length	2820		LF		
e	Piping Heat Trace, VLBTV Wire	2820	$ 15.75	LF	$ 44,415	4
f	Misc fittings and heat trace elements (30% of Groundwater Extraction Piping cost)	1	$ 42,853.50	LS	$ 42,854	
	Total Groundwater Extraction Piping				$ 185,699	
9	**Compressed Air Pipe and Fittings (2-Inch Carbon Steel)**	2820	$ 20.00	LF	$ 56,400	2
10	**Pipe Supports**	282	$ 200	LF	$ 56,400	
	CONSULTANT LABOR COST				$ 74,250	
	DIRECT COSTS w/10% MARKUP				$ 1,661,914	
	TOTAL WELL FIELD EQUIPMENT INSTALLTION COST				$ 1,736,164	

Cost Source Reference

1 QED Environmental Systems, Inc. Quote Dated May 16, 2008
2 2007 RS Means Database. Unit price shown includes 10% inflation rate and local area cost factor.
3 Unit rate assumed to be approximately 40% higher than rate for 6-inch carbon steel pipe and fittings with fiberglass insulation and aluminum jacket.
4 2006 Raychem quote obtained by CH2MHILL

Appendix J
Table 7.4
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Instrumentation and Controls Installation

Item	Consultant Labor and Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
1	**Steam Injection Wells**					
a	Pressure Gage (0-300 PSI)	68	$ 48	/Each	$ 3,264	1
b	Temperature Indicator	68	$ 127	/Each	$ 8,636	1
c	Orifice Plate and Transmitter	10	$ 10,000	/Each	$ 100,000	
	Total Steam Injection Wells and Piping I&Cs				$ 111,900	
2	**Groundwater Exraction Pressure Gage (0-300 PSI)**	37	$ 48	/Each	$ 1,776	1
3	**Vapor Extraction Vacuum Gage (30 in Hg)**	37	$ 50	/Each	$ 1,865	1
4	**Thermocouple String**					
a	Type T Thermocouple Wire (24 Gauge w/Fiberglass Insulation and Jacket)	1,305	$ 0.75	/Foot	$ 979	2
b	Analog Decoder	1	$ 500	/Each	$ 500	
	Cost per Temp Monitoring Point				$ 1,479	
	Number of Temperature Monitoring Points				14	
	Total Thermocouple String				20,703	
5	**Field Technician - Installation of Items 1 Through 4 (Instrumentation and Controls)** (Consultant Labor - Not Subject to Markup)	220	$ 75	/Hour	$ 16,500	
6	**Electrical Allowance (20% of Instrumentation and Controls cost)**	1	$ 40,873	/LS	$ 40,873	
7	**Control System Allowance (30% of Instrumentation and Controls cost)**	1	$ 54,497	/LS	$ 54,497	
	CONSULTANT LABOR COST				$ 16,500	
	DIRECT COSTS w/10% MARKUP				$ 254,775	
	TOTAL INSTRUMENTATION AND CONTROLS INSTALLATION COST				$ 271,275	

Cost Source Reference
1 Grainger Catalog Price
2 McMaster-Carr Catalog Price

Appendix J
Table 7.5
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Treatment Equipment Installation

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
1		**Vapor Treatment**					
	a	12,000-gallon Brine Holding Tank	1	$ 18,538	/Each	$ 18,538	1
	b	Fin-Fan Heat Exchanger	1	$ 14,306	/Each	$ 14,306	2
	c	Steam-Regenerable Carbon System					
		(incl. two 5,000-lb GAC vessels, condenser, separator, and inline stack PID)	1	$ 750,000	/LS	$ 750,000	3
	d	Interconnecting Piping (20% of Steam-Regen Carbon System cost)	1	$ 150,000	/LS	$ 150,000	
	e	5000-lb Polishing Vapor-Phase GAC Vessel	2	$ 16,000	/Each	$ 32,000	4
	f	Orifice Plate and Transmitter	2	$ 10,000	/Each	$ 20,000	
	g	1000 SCFM Liquid Ring Vacuum Blower (standard cast iron construction)	2	$ 80,000	/Each	$ 160,000	5
	h	Moisture Separator	1	$ 4,000	/Each	$ 4,000	6
	i	500-Gallon Collection Tank	1	$ 2,078	/Each	$ 2,078	1
	j	Transfer Pump (50 gpm)	9	$ 536	/Each	$ 4,820	7
		Total for Vapor Treatment				**$ 1,155,742**	
2		**Groundwater Exraction and Treatment**					
	a	Shell and Tube Heat Exchanger	1	$ 22,112	/Each	$ 22,112	8
	b	DNAPL/Water Separator	2	$ 56,450	/Each	$ 112,900	9
	c	Groundwater Holding Tank	1	$ 50,000	/Each	$ 50,000	
	d	Two 3,000-lb Liquid-Phase GAC Vessels Each w/Initial Virgin Coconut Shell GAC Fill	1	$ 16,830	LS	$ 16,830	10
	e	Air Compressor	1	$ 20,000	/Each	$ 20,000	11
	f	500-Gallon Collection Tank	1	$ 2,078	/Each	$ 2,078	1
	g	Cooling Tower (540 gpm Recirculation Rate)	1	$ 37,713	/Each	$ 37,713	12
	h	Transfer Pump (50 gpm)	8	$ 536	/Each	$ 4,284	7
	i	Transfer Pump (540 gpm)	2	$ 2,756	/Each	$ 5,513	13
	j	Transfer Pump (145 gpm)	2	$ 1,348	/Each	$ 2,696	7
	k	HiPOx System (100 gpm)	1	$ 1,025,000	/Each	$ 1,025,000	14
		Total for Groundwater Exraction and Treatment Equipment				**$ 1,299,126**	
3		**Equipment Pads and Containment**	1	$ 150,000	/LS	**$ 150,000**	11
4		**80' X 110' Treatment Plant Building**	1	$ 150,000	/LS	**$ 150,000**	
5		**Subcontractor Installation Cost**	1	$ 365,000	/LS	**$ 365,000**	15
		TOTAL TREATMENT EQUIPMENT INSTALLATION COST w/10% MARKUP				**$ 3,431,854**	

Cost Source Reference
1 Harrington Plastic Catalog Price
2 Heat Exchanger Sales and Engineering Company, LLC Quote Dated July 17, 2008
3 MEGTEC Systems, Inc. Quote Dated April 20, 2008
4 BakerCorp Quote Dated July 1, 2008
5 Yardley Pump and Vacuum Quote Dated July 18, 2008
6 Verbal Qoute from Enviro Supply and Services
7 Grainger Catalog Price
8 SEC Heat Exchanger Quote Dated July 1, 2008
9 Pan America Environmental Quote Dated July 28, 2008
10 BakerCorp Quoted Dated July 23, 2008
11 McMillan-McGee November 2006 Feasibility Study for Steam Injection, Page 34
12 Cooling Tower Systems Quote Dated July 2, 2008
13 McMaster-Carr Catalog Price
14 Unit Price scaled down to a 100 gpm system from $2,050,000 quote from Applied Process Technologies (June 6, 2006) for a 200 gpm system.
15 Verbal Quote from J.C. Palomar Construction, Inc.

Appendix J
Table 7.6
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Construction Management

Item	Consultant Labor	Quantity	Unit Cost		Cost
1	Project Manager	165	$150	/Hour	$ 24,750
2	Senior Engineer/Geologist	320	$125	/Hour	$ 40,000
3	Mid-Level Engineer/Geologist	880	$100	/Hour	$ 88,000
4	Junior/Field Engineer/Geologist	1,120	$ 75	/Hour	$ 84,000
5	Field Technician	1,120	$ 75	/Hour	$ 84,000
6	Clerical/Drafting	130	$ 50	/Hour	$ 6,500
	TOTAL CONSTRUCTION MANAGEMENT COST				$327,250

Appendix J
Table 7.7
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Hot Floor Pre-Heat

Item	Consultant Labor (Operations)	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	40	$ 150	/Hour	$ 6,000	
2	Senior Engineer/Geologist	40	$ 125	/Hour	$ 5,000	
3	Mid-Level Engineer/Geologist (One Full Time Mid-Level Engineer)	160	$ 100	/Hour	$ 16,000	
4	Junior/Field Engineer/Geologist (One Full Time Junior Engineer)	160	$ 75	/Hour	$ 12,000	
5	Field Technician (Three Full Time Operators - 40 Hours per Week Each)	480	$ 75	/Hour	$ 36,000	
6	Clerical/Drafting	40	$ 50	/Hour	$ 2,000	
	Consultant Labor Cost for Operations				**$ 77,000**	

Item	Consultant Labor (Reporting, H&S, Data Mngt, and Website Maintenance)	Quantity	Unit Cost		Cost	Cost Ref.
7	Project Manager	8	$ 150	/Hour	$ 1,200	
8	Senior Engineer/Geologist	8	$ 125	/Hour	$ 1,000	
9	Mid-Level Engineer/Geologist	62	$ 100	/Hour	$ 6,240	
10	Junior/Field Engineer/Geologist	160	$ 75	/Hour	$ 12,000	
11	Field Technician	0	$ 75	/Hour	$ -	
12	Clerical/Drafting	20	$ 50	/Hour	$ 1,000	
	Consultant labor for Reporting, H&S, Data Mngt, and Website Maintenance				**$ 21,440**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
13	**Equipment Rentals**					
a	29-million BTUs/hr Low NOx Steam Generator (incl. water softening package)	1	$ 70,000	/Month	$ 70,000	1
b	12-million BTUs/hr Low NOx Steam Generator (incl. water softening package)	0	$ 18,500	/Month	$ -	2
	Total Equipment Rentals				**$ 70,000**	
14	**Consumables (Excluding Utilities)**					
a	Salt for Steam Generator Feed Water Treatment	4	$ 580	/Week	$ 2,320	
b	Virgin Coconut Shell Vapor-Phase Carbon	0	$ 1.07	/lb	$ -	3
c	Vapor-Phase Carbon Change-Out Service	0	$ 1,850	/Change-Out	$ -	3
d	Hydrogen Peroxide for HiPOx	3,472	$ 3.00	/Gal	$ 10,416	
e	Oxygen for HiPOx	24,273	$ 0.35	/100 SCF	$ 8,496	
f	3000-lb Liquid-Phase Carbon Change-Out (Includes T&D as Hazardous Waste)	1	$ 6,746	/Each	$ 6,746	4
	Total Consumables				**$ 27,977**	

Appendix J
Table 7.7
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Hot Floor Pre-Heat

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
15		**Waste Management**					
	a	Vapor-Phase GAC Disposal (Listed Waste for Incineration)	0	$ 0.71	/lb	$ -	5
	b	Vapor-Phase GAC Transportation	0	$ 4,286	/Load	$ -	5
	c	Carbon Regen System Solvent Waste Disposal (Listed Waste for Incineration)	0	$ 0.50	/lb	$ -	6
	d	Carbon Regen System Solvent Waste Transportation	0	$ 3,650	/Load	$ -	6
	e	Filtration Generated Waste Disposal (Listed Waste for Incineration)	901	$ 0.25	/lb	$ 225	6
	f	Filtration Generated Waste Transportation (filtration waste generated during hot floor pre-heat will be transported during O&M)	0	$ 2,800	/Load	$ -	6
	g	Boiler Water Pre-Treatment Brine and Blowdown Off-Site Disposal (non-Haz)	86,475	$ 0.14	/Gal	$ 12,106	7
	h	Boiler Water Pre-Treatment Brine and Blowdown Transportation	9	$ 950	/10,000 Gals	$ 8,550	7
		r				**$ 20,882**	
16		**Lab Analytical and Monitoring**					
	a	Summa Can Rental	13	$ 40	/Each	$ 520	8
	b	Vapor Analysis - VOCs (EPA Method TO-15)	13	$ 200	/Each	$ 2,600	8
	c	Water Analysis - Pesticides (EPA Method 8081A)	13	$ 90	/Each	$ 1,170	9
	d	Water Analysis - VOCs (EPA Method 8260B)	13	$ 95	/Each	$ 1,235	9
	e	Water Analysis - pCBSA (Modifed EPA Method 314.0)	2	$ 80	/Each	$ 160	9
	f	Tedlar Bags	20	$ 10	/Each	$ 200	
	g	TVA-1000B PID/FID Rental	1	$ 1,200	/Month	$ 1,200	10
		Total Lab Analytical and Monitoring				**$ 7,085**	
17		**Miscellaneous**					
	a	Temporary Office 24'x60' Delivery and Setup	1	$ 2,939	/Each	$ 2,939	11
	b	Temporary Office 24'x60' Rental	1	$ 1,030	/Month	$ 1,030	11
	c	Temporary Office 24'x60' Demobilization	0	$ 1,746	/Each	$ -	11
	d	Temporary Storage Trailer	1	$ 149	/Month	$ 149	12
	e	Portable Toilet Delivery	1	$ 22	/Each	$ 22	13
	f	Portable Toilet Rental	1	$ 76	/Month	$ 76	13
	g	Standby Generator (800 kW)	1	$ 8,775	/Month	$ 8,775	14
	h	Maintenance Parts	1	$ 1,000	/Month	$ 1,000	
	i	Fed Ex and Deliveries	20	$ 150	/Day	$ 3,000	
	j	Temporary office comm. (internet, telephone, fax)	1	$ 1,000	/Month	$ 1,000	
	k	Operator Truck Usage (One Truck per Operator)	20	$ 100	/Day/Truck	$ 2,000	
		Total Miscellaneous				**$ 19,989**	

Appendix J
Table 7.7
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Hot Floor Pre-Heat

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
18	Steam License for Hot Floor	25,711	$ 0.50	/CY Treated	$ 12,856	15
	Total Subcontractor Cost				$ 158,789	

Item	Utilities	Quantity	Unit Cost		Cost	Cost Ref.
19	Electricity Usage	211,420	$ 0.1045	/kWh	$ 22,093	16
20	Natural Gas for Steam Generation	199,901	$ 1.14	/Therm	$ 227,888	17
21	Municipal Water for Cooling Tower Water Makeup (5 GPM)	219,000	$ 0.0029	/Gal	$ 635	
22	Municipal Water for Steam Generation	1,121,152	$ 0.0029	/Gal	$ 3,251	
	Total Utilities				$ 253,867	

CONSULTANT LABOR COST	$ 98,440
SUBCONTRACTOR COST w/10% MARKUP	$ 174,667
UTILITIES COST (NO MARKUP)	$ 253,867
TOTAL COST FOR HOT FLOOR PRE-HEAT	$ 526,975

Cost Source Reference

1 Nationwide Boiler Quote Dated May 16, 2008
2 Nationwide Boiler Quote Dated July 30, 2008
3 BakerCorp Quote Dated June 30, 2008
4 BakerCorp Quote July 23, 2008
5 NRC Environmental Services, Inc. Quote Dated June 30, 2008
6 Clean Harbors Quote Dated October 10, 2007
7 NRC Environmental Services, Inc. Email Quote Dated July 18, 2008
8 Verbal Quote from Calscience Environmental Laboratories, Inc.
9 Verbal Quote from Test America
10 Verbal Quote from Ashtead Technology Rentals
11 Mobile Mini, Inc. Quote Dated October 11, 2007
12 Verbal Quote from Mobile Mini, Inc.
13 Verbal Quote from A-1 Coast Port-A-Toilet
14 Kohler Rental Quote Dated June 30, 2008
15 McMillan-McGee November 2006 Feasibility Study for Steam Injection, Page 33
16 Shedule A-3 LADWP Rate (Second Quarter 2008)
17 GN-10, Tier III, SoCal Gas Co. Rate (Effective May 1, 2008)

Appendix J
Table 7.8
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Operations and Maintenance

Item	Consultant Labor (Operations)	Quantity	Unit Cost			Cost	Cost Ref.
1	Project Manager	520	$	150	/Hour	$ 78,000	
2	Senior Engineer/Geologist	520	$	125	/Hour	$ 65,000	
3	Mid-Level Engineer/Geologist (One Full Time Mid-Level Engineer)	2,080	$	100	/Hour	$ 208,000	
4	Junior/Field Engineer/Geologist (One Full Time Junior Engineer)	2,080	$	75	/Hour	$ 156,000	
5	Field Technician (Three Full Time Operators - 40 Hours per Week Each)	6,240	$	75	/Hour	$ 468,000	
6	Clerical/Drafting	520	$	50	/Hour	$ 26,000	
	Consultant Labor Cost for Operations					**$ 1,001,000**	

Item	Consultant Labor (Reporting, H&S, Data Mngt, and Website Maintenance)	Quantity	Unit Cost			Cost	Cost Ref.
7	Project Manager	20	$	150	/Hour	$ 3,000	
8	Senior Engineer/Geologist	80	$	125	/Hour	$ 10,000	
9	Mid-Level Engineer/Geologist	1,300	$	100	/Hour	$ 130,000	
10	Junior/Field Engineer/Geologist	2,080	$	75	/Hour	$ 156,000	
11	Field Technician	0	$	75	/Hour	$ -	
12	Clerical/Drafting	180	$	50	/Hour	$ 9,000	
	Consultant labor for Reporting, H&S, Data Mngt, and Website Maintenance					**$ 308,000**	

Item	Subcontractor Cost	Quantity	Unit Cost			Cost	Cost Ref.
13	**Equipment Rentals**						
a	29-million BTUs/hr Low NOx Steam Generator (incl. water softening package)	12	$	70,000	/Month	$ 840,000	1
b	12-million BTUs/hr Low NOx Steam Generator (incl. water softening package)	0	$	18,500	/Month	$ -	2
	Total Equipment Rentals					**$ 840,000**	
14	**Consumables (Excluding Utilities)**						
a	Salt for Steam Generator Feed Water Treatment	46	$	580	/Week	$ 26,772	
b	Virgin Coconut Shell Vapor-Phase Carbon (7,000-lbs of polishing GAC per month plus 10,000 lbs of regen system carbon changed-out after six months)	94,000	$	1.07	/lb	$ 100,580	3
c	Vapor-Phase Carbon Change-Out Service	10	$	1,739	/Change-Out	$ 17,390	3
d	Hydrogen Peroxide for HiPOx	166,650	$	3.00	/Gal	$ 499,950	
e	Oxygen for HiPOx	1,165,100	$	0.35	/100 SCF	$ 407,785	
f	3000-lb Liquid-Phase Carbon Change-Out (Includes T&D as Hazardous Waste)	48	$	6,746	/Each	$ 323,808	4
	Total Consumables					**$ 1,376,285**	

Appendix J
Table 7.8
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Operations and Maintenance

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
15		**Waste Management**					
	a	Vapor-Phase GAC Disposal (Listed Waste for Incineration) (incl. 10,000 lbs of regen system carbon at year end)	80,000	$ 0.71	/lb	$ 56,800	5
	b	Vapor-Phase GAC Transportation	5	$ 4,286	/Load	$ 21,430	5
	c	Carbon Regen System Solvent Waste Disposal (Listed Waste for Incineration)	169,500	$ 0.50	/lb	$ 84,750	6
	d	Carbon Regen System Solvent Waste Transportation	5	$ 3,650	/Load	$ 18,250	6
	e	Filtration Generated Waste Disposal (Listed Waste for Incineration)	39,300	$ 0.25	/lb	$ 9,825	6
	f	Filtration Generated Waste Transportation	4	$ 2,800	/Load	$ 11,200	6
	g	Boiler Water Pre-Treatment Brine and Blowdown Off-Site Disposal (non-Haz)	926,672	$ 0.14	/Gal	$ 129,734	7
	h	Boile Water Pre-Treatment Brine and Blowdown Transportation	93	$ 950	/10,000 Gals	$ 88,350	7
		Total Waste Management				**$ 420,339**	
16		**Lab Analytical and Monitoring**					
	a	Summa Can Rental	176	$ 40	/Each	$ 7,040	8
	b	Vapor VOCs Analysis (EPA Method TO-15)	176	$ 200	/Each	$ 35,200	8
	c	Liquid Pesticides (EPA Method 8260B)	176	$ 90	/Each	$ 15,840	9
	d	Liquid VOC Analysis (EPA Method 8081A)	176	$ 95	/Each	$ 16,720	9
	e	Liquid pCBSA Analysis (Modifed EPA Method 314.0)	24	$ 80	/Each	$ 1,920	9
	f	Tedlar Bags	240	$ 10	/Each	$ 2,400	
	g	TVA-1000B PID/FID Rental	12	$ 1,200	/Month	$ 14,400	10
		Total Lab Analytical and Monitoring				**$ 93,520**	
17		**Miscellaneous**					
	a	Temporary Office 24'x60' Delivery and Setup	0	$ 2,939	/Each	$ -	11
	b	Temporary Office 24'x60' Rental	12	$ 1,030	/Month	$ 12,356	11
	c	Temporary Office 24'x60' Demobilization	1	$ 1,746	/Each	$ 1,746	11
	d	Temporary Storage Trailer	12	$ 149	/Month	$ 1,784	12
	e	Portable Toilet Delivery	0	$ 22	/Each	$ -	13
	f	Portable Toilet Rental	12	$ 76	/Month	$ 908	13
	g	Standby Generator (800 kW)	12	$ 8,775	/Month	$ 105,300	14
	h	Maintenance Parts	12	$ 1,000	/Month	$ 12,000	
	i	Fed Ex and Deliveries	260	$ 150	/Day	$ 39,000	
	j	Temporary office comm. (internet, telephone, fax)	12	$ 1,000	/Month	$ 12,000	
	k	Operator Truck Usage (One Truck per Operator)	520	$ 100	/Day/Truck	$ 52,000	
		Total Miscellaneous				**$ 237,094**	

Appendix J
Table 7.8
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Operations and Maintenance

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
18	Steam License for UBA	57,665	$ 0.50	/CY Treated	$ 28,833	15
	Total Subcontractor Cost (O&M Year 1)				$ 2,996,071	

Item	Utilities	Quantity	Unit Cost		Cost	Cost Ref.
19	Electricity Usage	10,148,151	$ 0.1045	/kWh	$ 1,060,482	16
20	Natural Gas for Steam Generation	2,149,985	$ 1.14	/Therm	$ 2,450,983	17
21	Municipal Water for Cooling Water Tower Makeup (5 GPM)	2,628,000	$ 0.0029	/Gal	$ 7,621	
22	Municipal Water for Steam Generation	12,022,037	$ 0.0029	/Gal	$ 34,864	
	Total Utilities				$ 3,553,950	

FULL SCALE CONSULTANT LABOR COST	$ 1,309,000	
FULL SCALE SUBCONTRACTOR COST w/10% MARKUP	$ 3,295,678	
UTILITIES COST (NO MARKUP)	$ 3,553,950	
TOTAL OPERATIONS AND MAINTENANCE COST	$ 8,158,628	

Cost Source Reference

1 Nationwide Boiler Quote Dated May 16, 2008
2 Nationwide Boiler Quote Dated July 30, 2008
3 BakerCorp Quote Dated June 30, 2008. Unit price for carbon change-out services is scaled down for a 9,400-lb change-out from BakerCorp quote of $1,850 per change-out for 10,000 lbs.
4 BakerCorp Quote July 23, 2008
5 NRC Environmental Services, Inc. Quote Dated June 30, 2008
6 Clean Harbors Quote Dated October 10, 2007
7 NRC Environmental Services, Inc. Email Quote Dated July 18, 2008
8 Verbal Quote from Calscience Environmental Laboratories, Inc.
9 Verbal Quote from Test America
10 Verbal Quote from Ashtead Technology Rentals
11 Mobile Mini, Inc. Quote Dated October 11, 2007
12 Verbal Quote from Mobile Mini, Inc.
13 Verbal Quote from A-1 Coast Port-A-Toilet
14 Kohler Rental Quote Dated June 30, 2008
15 McMillan-McGee November 2006 Feasibility Study for Steam Injection, Page 33
16 Shedule A-3 LADWP Rate (Second Quarter 2008)
17 GN-10, Tier III, SoCal Gas Co. Rate (Effective May 1, 2008)

Appendix J
Table 7.9
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Well Abandonment

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	50	$ 150	/Hour	$ 7,500	
2	Senior Engineer/Geologist	232	$ 125	/Hour	$ 29,000	
3	Mid-Level Engineer/Geologist	125	$ 100	/Hour	$ 12,500	
4	Junior/Field Engineer/Geologist	1,184	$ 75	/Hour	$ 88,800	
5	Field Technician	50	$ 75	/Hour	$ 3,750	
6	Clerical/Drafting	50	$ 50	/Hour	$ 2,500	
	Total Consultant Labor Cost				$ 144,050	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
1	**Mobilization/Demobilization of Drill Rig**	1	$ 2,000	/LS	**$ 2,000**	1
2	**Abandon UBA Multi-Phase Extraction Wells**					
a	Drill out well materials	105	$ 65	/Foot	$ 6,825	1
b	Grout resulting boring	105	$ 30	/Foot	$ 3,150	1
c	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
d	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
e	Vehicle Usage	1	$ 100	/Day	$ 100	
f	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
g	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 11,075	
	Number of Wells				27	
	Total for UBA Multi-Phase Extraction Well Adandonment				**299,025**	
3	**Abandon Triple-Nested UBA Steam Injecton Wells**					
a	Drill out well materials	60	$ 65	/Foot	$ 3,900	1
b	Grout resulting boring	60	$ 30	/Foot	$ 1,800	1
c	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
d	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
e	Vehicle Usage	1	$ 100	/Day	$ 100	
f	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
g	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 6,800	
	Number of Wells				14	
	Total for UBA Triple-Nested Steam Injection Well Abandonment				**95,200**	
4	**Abandon Hot Floor Multi-Phase Extraction Wells**					
a	Pressure grout well	105	$ 30	/Foot	$ 3,150	1
b	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
c	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
f	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 4,250	
	Number of Wells				10	
	Total for Hot Floor Multi-Phase Extraction Well Abandonment				**$ 42,500**	
5	**Abandon Hot Floor Steam Injection Wells**					
a	Pressure grout well	105	$ 30	/Foot	$ 3,150	1
b	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
c	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
f	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 4,250	
	Number of Wells				26	
	Total for Hot Floor Steam Injection Well Abandonment				**$ 110,500**	

Appendix J
Table 7.9
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Well Abandonment

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
6	**Abandon Temperature Monitoring Points**					
a	Pressure grout well	105	$ 30	/Foot	$ 3,150	1
b	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
c	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
f	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 4,250	
	Number of Wells				14	
	Total for Temperature Monitoring Point Abandonment				$ 59,500	
7	**Waste Management**					
a	Waste Tank Rental	0	$ 38	/Day	$ -	
b	Waste Tank Rental Delivery - Mob and Demob	0	$ 900	/Each	$ -	
c	Waste Bin Rental	540	$ 15	/Day	$ 8,100	2
d	Waste Bin Rental Delivery - Mob and Demob	18	$ 500	/Each	$ 9,000	2
e	Transport of Hazardous Soil Cuttings	18	$ 1,100	/Each	$ 19,800	2
f	Disposal of Hazardous Soil Cuttings	269	$ 550	/Ton	$ 147,950	2
g	Transport of Hazardous Mud	0	$ 500	/Each	$ -	
h	Disposal of Hazardous Mud	0	$ 1.1	/Gal	$ -	
i	Transport of Hazardous Water	1	$ 1,100	/Each	$ 1,100	2
j	Disposal of Hazardous Water	1982	$ 0.8	/Gal	$ 1,586	2
k	Waste Characterization/Profiling	2	$ 500	/Each	$ 1,000	
	Total Waste Management				$ 188,536	
	Total Subcontractor Cost w/10% Markup				$ 876,987	

TOTAL WELL ABANDONMENT COST	$ 1,021,037

Cost Source Reference
1 Verbal Quote from Water Development Corporation
2 Verbal Quote from NRC Environmental Services

Appendix J
Table 7.10
Steam Injection (2 UBA PVs and 2.5 Hot Floor PVs)
Demobilization

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	60	$ 150	/Hour	$ 9,000	
2	Senior Engineer/Geologist	200	$ 125	/Hour	$ 25,000	
3	Mid-Level Engineer/Geologist	654	$ 100	/Hour	$ 65,400	
4	Junior/Field Engineer/Geologist	800	$ 75	/Hour	$ 60,000	
5	Field Technician	425	$ 75	/Hour	$ 31,875	
6	Clerical/Drafting	140	$ 50	/Hour	$ 7,000	
	Consultant Labor Cost				**$ 198,275**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Remove Purchased Treatment Equipment**	1	$ 317,000	/LS	**$ 317,000**	
8	**Close-Out Borings**					
a	Drilling	9	$ 12,000	/Boring	$ 108,000	1
b	Waste Disposal	9	$ 5,500	/Boring	$ 49,500	2
c	Soil Pesticides (EPA Method 8081A)	54	$ 90	/Sample	$ 4,860	3
d	Soil VOCs (EPA Method 8260B)	54	$ 95	/Sample	$ 5,130	3
e	Soil pCBSA (Modified EPA Method 314.0)	54	$ 80	/Sample	$ 4,320	3
f	Liquid Pesticides (EPA Method 8081A)	9	$ 90	/Sample	$ 810	3
g	Liquid VOCs (EPA Method 8260B)	9	$ 95	/Sample	$ 855	3
h	Liquid pCBSA (Modified EPA Method 314.0)	9	$ 80	/Sample	$ 720	3
	Total for Close-Out Borings				**$ 174,195**	
	Total Subcontractor Cost w/10% Markup				**$ 540,315**	

	TOTAL DEMOBILIZATION COST	**$ 738,590**

Cost Source Reference
1 Verbal Quote from Water Development Corporation
2 Verbal Quote from NRC Environmental Services
3 Verbal Quote from Test America

Appendix J
Table 8.0
Cost Summary
Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Focused Treatment Area

Discount Rate 4%

Year	Activity	Detailed Cost Table	Cost (Undiscounted)	Cost (NPV)
1	Focused Treatment Design	J-8.1 Design and Permitting	$ 1,293,125	$ 1,243,389
2	Focused Treatment Build	J-8.2 Well Construction	$ 5,374,953	$ 10,782,238
		J-8.3 Well Field Equipment Installation	$ 1,736,164	
		J-8.4 Instrumentation and Controls Installation	$ 271,275	
		J-8.5 Treatment Equipment Installation	$ 3,426,553	
		J-8.6 Construction Management	$ 327,250	
		J-8.7 Hot Floor Pre-Heat	$ 525,875	
3	Focused Treatment Operation and Maintenance	J-8.8 Operations and Maintenance	$ 9,553,968	$ 8,493,443
4	Verification and Abandonment	J-8.9 Well Abandonment	$ 1,021,037	$ 1,504,136
		J-8.10 Demobilization	$ 738,590	

Total NPV at 4 Years	**$ 22,023,207**
Total Undiscounted Cost	**$ 24,268,789**

Appendix J
Table 8.1
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Design and Permitting

Item	Consultant Labor	Quantity	Unit Cost		Cost
1	Project Manager	890	$ 150	/Hour	$ 133,500
2	Senior Engineer/Geologist	1,320	$ 125	/Hour	$ 165,000
3	Mid-Level Engineer/Geologist	5,200	$ 100	/Hour	$ 520,000
4	Junior/Field Engineer/Geologist	3,735	$ 75	/Hour	$ 280,125
5	Field Technician	0	$ 75	/Hour	$ -
6	Clerical/Drafting	1,250	$ 50	/Hour	$ 62,500
	Consultant Labor				**$ 1,161,125**

Item	Subcontractor Cost	Quantity	Unit Cost		Cost
7	**Outside Thermal Expert**	1	$ 120,000	/LS	**$ 120,000**
	Subcontractor Cost w/10% Markup				**$ 132,000**

	TOTAL DESIGN AND PERMITTING COST	**$ 1,293,125**

Appendix J
Table 8.2
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Well Construction

Item	Consultant Labor	Quantity	Unit Cost			Cost		Cost Ref.
1	Project Manager	560	$	150	/Hour	$	84,000	
2	Senior Engineer/Geologist	560	$	125	/Hour	$	70,000	
3	Mid-Level Engineer/Geologist	2,234	$	100	/Hour	$	223,400	
4	Junior/Field Engineer/Geologist	3,432	$	75	/Hour	$	257,400	
5	Field Technician	540	$	75	/Hour	$	40,500	
6	Clerical/Drafting	560	$	50	/Hour	$	28,000	
	Total Consultant Labor Cost					**$**	**703,300**	

Item	Subcontractor Cost	Quantity	Unit Cost			Cost		Cost Ref.
7	**Abandon Existing Site Wells Prior to Thermal Treatment**							
a	Drill out well materials	90	$	65	/Foot	$	5,850	1
b	Grout resulting boring	90	$	30	/Foot	$	2,700	1
c	Forklift and mini-hopper	1	$	500	/Day	$	500	1
d	Excavate and remove well box	1	$	2,000	/LS	$	2,000	1
e	Abandonment Crew per Diem	1	$	200	/Night	$	200	
f	Vehicle Usage	1	$	100	/Day	$	100	
g	Equipment Rental and Supplies	1	$	150	/Day	$	150	
h	Other Direct Costs	1	$	150	/Day	$	150	
	Cost per Well					$	11,650	
	Number of Wells						5	
	Total for Existing Site Well Abandonment					**$**	**58,250**	

Appendix J
Table 8.2
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Well Construction

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
8		**UBA Multi-Phase Extraction Wells (12" HSA Drilling to 108' bgs)**					
	a	Install Well Constructed of 6" LCS Casing w/ 60' of SS Screen and 3-foot Sump, Type II Cement Grout, and Sand Pack	1	$ 12,000	/Each	$ 12,000	2
	b	Forklift and Hopper Rental for Waste Handling	1	$ 250	/Day	$ 250	2
	c	Drill Crew per Diem	1	$ 450	/Night	$ 450	2
	d	Vehicle Usage	1	$ 100	/Day	$ 100	
	e	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
	f	Other Direct Costs	1	$ 300	/Day	$ 300	
		Cost per Well				$ 13,600	
		Number of Wells (1 Well Installed per Day)				27	
		Subtotal - UBA Multi-Phase Extraction Wells				**$ 367,200**	
9		**Lab Analytical (Sixteen UBA Multi-Phase Extraction Well Borings)**					
	a	Soil Analysis - Pesticides (EPA Method 8081A)	54	$ 90	/Sample	$ 4,860	3
	b	Soil Analysis - VOCs (EPA Method 8260B)	54	$ 95	/Sample	$ 5,130	3
	c	Soil Analysis - pCBSA (Modified EPA Method 314.0)	54	$ 80	/Sample	$ 4,320	3
	d	Water Analysis - Pesticides (EPA Method 8081A)	9	$ 90	/Sample	$ 810	3
	e	Water Analysis - VOCs (EPA Method 8260B)	9	$ 95	/Sample	$ 855	3
	f	Water Analysis - pCBSA (Modified EPA Method 314.0)	9	$ 80	/Sample	$ 720	3
		Total Lab Analytical (UBA Extraction Wells)				**$ 16,695**	

Appendix J
Table 8.2
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
10	**Triple-Nested UBA Steam Injecton Wells (12" HSA Drilling to 105' bgs)**					
a	Install and Well Constructed of Three 2" LCS Casings each w/ 5' of SS Screen, Type II Cement Grout, and Sand Pack. Total casing depths are 75, 90, and 105' bgs	1	$ 7,000	/Each	$ 7,000	2
b	Forklift and Hopper Rental for Waste Handling	1	$ 250	/Day	$ 250	2
c	Drill Crew per Diem	1	$ 450	/Night	$ 450	2
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
f	Other Direct Costs	1	$ 300	/Day	$ 300	
	Cost per Well				$ 8,600	
	Number of Wells (1 Well Installed per Day)				14	
	Subtotal - Triple-Nested UBA Steam Injecton Wells				**$ 120,400**	
11	**Develop UBA Multi-Phase Extraction Wells and Triple-Nested UBA Steam Injection Wells**					
a	Development Rig	1	$ 2,000	/Day	$ 2,000	2
b	Development Crew per Diem	1	$ 200	/Night	$ 200	2
	Cost per Well				$ 2,200	
	Number of Wells (1 Well Developed per Day)				41	
	Subtotal - Develop UBA Wells				**$ 90,200**	

Appendix J
Table 8.2
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
12	**Mobilization/Demobilization of Mud Rotary Drill Rig**	2	$ 12,000	/Each	**$ 24,000**	4
13	**Hot Floor Multi-Phase Extraction Wells**					
a	Move Between Well Locations	1	$ 2,000	/Each	$ 2,000	4
b	Install 14", .25" Wall, Low Carbon Steel Conductor Casing with Type II Cement Grout	110	$ 220	/Foot	$ 24,200	4
c	Mud Change-Out and Pit Decon	1	$ 2,000	/Each	$ 2,000	4
d	12" Boring Under Conductor	8.5	$ 80	/Foot	$ 680	4
e	Install 6" Low Carbon Steel Sched. 40 Casing	110.5	$ 88	/Foot	$ 9,724	4
f	Install 6" Type 304 Stainless Steel Screen with 3' Sump	8	$ 175	/Foot	$ 1,400	4
g	Type II Cement Grout and Sand Pack	118.5	$ 30	/Foot	$ 3,555	4
h	Forklift and Hopper Rental for Waste Handling	4	$ 400	/Day	$ 1,600	4
i	Standby for Cement Curing	6	$ 550	/Hour	$ 3,300	4
j	Well Development	10	$ 165	/Hour	$ 1,650	4
k	Vehicle Usage	4	$ 100	/Day	$ 400	
l	Equipment Rental and Supplies	4	$ 500	/Day	$ 2,000	
m	Other Direct Costs	4	$ 300	/Day	$ 1,200	
	Cost per Well				$ 53,709	
	Number of Wells (4 Days per Well for Installation and Development)				10	
	Subtotal - Hot Floor Multi-Phase Extraction Wells				**$ 537,090**	

Appendix J
Table 8.2
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
14	**Hot Floor Steam Injecton Wells**					
a	Move Between Well Locations	1	$ 2,000	/Each	$ 2,000	4
b	Install 10", .25" Wall, Low Carbon Steel Conductor Casing with Type II Cement Grout	110	$ 180	/Foot	$ 19,800	4
c	Mud Change-Out	1	$ 1,500	/Each	$ 1,500	4
d	9" Boring Under Conductor	5.5	$ 75	/Foot	$ 413	4
e	Install 2" Low Carbon Steel Sched. 40 Casing	110.5	$ 45	/Foot	$ 4,973	4
f	Install 2" Type 304 Stainless Steel Screen	5	$ 90	/Foot	$ 450	4
g	Type II Cement Grout and Sand Pack	115.5	$ 20	/Foot	$ 2,310	4
h	Forklift and Hopper Rental for Waste Handling	4	$ 400	/Day	$ 1,600	4
i	Standby for Cement Curing	5	$ 550	/Hour	$ 2,750	4
j	Well Development	6	$ 165	/Hour	$ 990	4
k	Vehicle Usage	4	$ 100	/Day	$ 400	
l	Equipment Rental and Supplies	4	$ 500	/Day	$ 2,000	
m	Other Direct Costs	4	$ 300	/Day	$ 1,200	
	Cost per Well				$ 40,385	
	Number of Wells (4 Days per Well for Installation and Development)				26	
	Subtotal - Hot Floor Steam Injecton Wells				**$ 1,050,010**	
15	**Temperature Monitoring Points**					
a	Move Between Well Locations	1	$ 2,000	/Each	$ 2,000	4
b	Install 10", .25 Wall, Low Carbon Steel Conductor Casing with Type II Cement Grout	110	$ 180	/Foot	$ 19,800	4
c	Mud Change-Out	1	$ 1,500	/Each	$ 1,500	4
d	8" Boring Under Conductor	5	$ 75	/Foot	$ 375	4
e	Install 1.5" Low Carbon Steel Casing with Bottom Cap	115	$ 40	/Foot	$ 4,600	4
f	Type II Cement Grout	115	$ 20	/Foot	$ 2,300	4
g	Forklift and Hopper Rental for Waste Handling	5	$ 400	/Day	$ 2,000	4
h	Standby for Cement Curing	5	$ 550	/Hour	$ 2,750	4
i	Vehicle Usage	5	$ 100	/Day	$ 500	4
j	Equipment Rental and Supplies	5	$ 500	/Day	$ 2,500	
k	Other Direct Costs	5	$ 300	/Day	$ 1,500	
	Subtotal				$ 39,825	
	Number of Wells (3 Days per Point - no Development Needed)				14	
	Subtotal - Temperature Monitoring Points				**$ 557,550**	

Appendix J
Table 8.2
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
16	**BFS Monitoring Well Installation** (4 Days per Well for Installation and Development)	2	$ 54,000	/Well	$ 108,000	1
17	**Waste Management**					
a	Waste Tank Rental	2920	$ 38	/Day	$ 110,960	5
b	Waste Tank Rental Delivery - Mob and Demob	8	$ 900	/Each	$ 7,200	5
c	Waste Bin Rental	1710	$ 15	/Day	$ 25,650	5
d	Waste Bin Rental Delivery - Mob and Demob	57	$ 500	/Each	$ 28,500	5
e	Transport of Hazardous Soil Cuttings	57	$ 1,100	/Each	$ 62,700	5
f	Disposal of Hazardous Soil Cuttings	1134	$ 550	/Ton	$ 623,700	5
g	Transport of Hazardous Mud	87	$ 500	/Each	$ 43,500	5
h	Disposal of Hazardous Mud	322717	$ 1.1	/Gal	$ 354,989	5
i	Transport of Hazardous Water	15	$ 1,100	/Each	$ 16,500	5
j	Disposal of Hazardous Water	52954	$ 0.8	/Gal	$ 42,363	5
k	Waste Characterization/Profiling	3	$ 500	/Each	$ 1,500	
	Subtotal - Waste Management				**$ 1,317,562**	
	Total Subcontractor Cost w/10% Markup				**$ 4,671,653**	

TOTAL WELL CONSTRUCTION COST	**$ 5,374,953**

Cost Source Reference

1 Verbal Quote from Water Development Corporation
2 Cascade Drilling, Inc. Quote Dated 7/15/08
3 Verbal Quote from Test America
4 Water Development Corporation Quote Dated 4/25/08
5 Verbal Quote from NRC Environmental

Appendix J
Table 8.3
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Well Field Equipment Installation

Item	Consultant Labor and Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
1	**Electrical Service Upgrade**	1	$ 50,000	LS	**$ 50,000**	
2	**Natural Gas Pipeline**	1	$ 200,000	LS	**$ 200,000**	
3	**Groundwater Extraction Assemblies**					
a	Well Head Assemblies	37	$ 1,000	Each	$ 37,000	
b	Extraction Pump (High Temperature Hammerhead Pro)	37	$ 3,070	Each	$ 113,590	1
c	Downwell Air Supply Hose (3/8" SS Brainded, Teflon Lined)	3700	$ 11	LF	$ 40,700	1
d	Downwell Air Exhaust Hose (1/2" SS Brainded, Teflon Lined)	3700	$ 16	LF	$ 59,200	1
e	Downwell Discharge Hose (1/4" SS Brainded, Teflon Lined)	3700	$ 22	LF	$ 81,400	1
	Total Groundwater Extraction Assemblies				**$ 331,890**	
4	**Steam Injection Well Head Assemblies**	46	$ 7,000	Each	**$ 322,000**	
5	**Field Technician - Pump and Well Head Assembly Construction and Installation** (Consultant Labor - Not Subject to Markup)	990	$ 75	Hour	**$ 74,250**	
6	**Steam Injection Piping**					
a	6-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	570	$ 67.65	LF	$ 38,561	2
b	4-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1140	$ 43.45	LF	$ 49,533	2
c	2-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1190	$ 34.10	LF	$ 40,579	2
	Total Steam Injection Piping				**$ 128,673**	
7	**Vapor Extraction Piping**					
a	8-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	570	$ 94.71	LF	$ 53,985	3
b	6-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1140	$ 67.65	LF	$ 77,121	2
c	4-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1120	$ 43.45	LF	$ 48,664	2
	Total Vapor Extraction Piping				**$ 179,770**	

Appendix J
Table 8.3
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Well Field Equipment Installation

Item		Consultant Labor and Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
8		**Groundwater Extraction Piping**					
	a	4-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	560	$ 43.45	LF	$ 24,332	2
	b	2-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1140	$ 34.10	LF	$ 38,874	2
	c	1.5-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1120	$ 31.45	LF	$ 35,224	2
	d	Total Piping Length	2820		LF		
	e	Piping Heat Trace, VLBTV Wire	2820	$ 15.75	LF	$ 44,415	4
	f	Misc fittings and heat trace elements (30% of Groundwater Extraction Piping cost)	1	$ 42,853.50	LS	$ 42,854	
		Total Groundwater Extraction Piping				$ 185,699	
9		**Compressed Air Pipe and Fittings (2-Inch Carbon Steel)**	2820	$ 20.00	LF	$ 56,400	2
10		**Pipe Supports**	282	$ 200	LF	$ 56,400	
		CONSULTANT LABOR COST				$ 74,250	
		DIRECT COSTS w/10% MARKUP				$ 1,661,914	
		TOTAL WELL FIELD EQUIPMENT INSTALLTION COST				$ 1,736,164	

Cost Source Reference

1 QED Environmental Systems, Inc. Quote Dated May 16, 2008
2 2007 RS Means Database. Unit price shown includes 10% inflation rate and local area cost factor.
3 Unit rate assumed to be approximately 40% higher than rate for 6-inch carbon steel pipe and fittings with fiberglass insulation and aluminum jacket.
4 2006 Raychem quote obtained by CH2MHILL

Appendix J
Table 8.4
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Instrumentation and Controls Installation

Item	Consultant Labor and Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
1	**Steam Injection Wells**					
a	Pressure Gage (0-300 PSI)	68	$ 48	/Each	$ 3,264	1
b	Temperature Indicator	68	$ 127	/Each	$ 8,636	1
c	Orifice Plate and Transmitter	10	$ 10,000	/Each	$ 100,000	
	Total Steam Injection Wells and Piping I&Cs				$ 111,900	
2	**Groundwater Exraction Pressure Gage (0-300 PSI)**	37	$ 48	/Each	$ 1,776	1
3	**Vapor Extraction Vacuum Gage (30 in Hg)**	37	$ 50	/Each	$ 1,865	1
4	**Thermocouple String**					
a	Type T Thermocouple Wire (24 Gauge w/Fiberglass Insulation and Jacket)	1,305	$ 0.75	/Foot	$ 979	2
b	Analog Decoder	1	$ 500	/Each	$ 500	
	Cost per Temp Monitoring Point				$ 1,479	
	Number of Temperature Monitoring Points				14	
	Total Thermocouple String				20,703	
5	**Field Technician - Installation of Items 1 Through 4 (Instrumentation and Controls)** (Consultant Labor - Not Subject to Markup)	220	$ 75	/Hour	$ 16,500	
6	**Electrical Allowance (20% of Instrumentation and Controls cost)**	1	$ 40,873	/LS	$ 40,873	
7	**Control System Allowance (30% of Instrumentation and Controls cost)**	1	$ 54,497	/LS	$ 54,497	
	CONSULTANT LABOR COST				$ 16,500	
	DIRECT COSTS w/10% MARKUP				$ 254,775	
	TOTAL INSTRUMENTATION AND CONTROLS INSTALLATION COST				$ 271,275	

Cost Source Reference
1 Grainger Catalog Price
2 McMaster-Carr Catalog Price

Appendix J
Table 8.5
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Treatment Equipment Installation

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
1	**Vapor Treatment**					
	12,000-gallon Brine Holding Tank	1	$ 18,538	/Each	$ 18,538	1
	Fin-Fan Heat Exchanger	1	$ 14,306	/Each	$ 14,306	2
	Steam-Regenerable Carbon System					
	(incl. two 5,000-lb GAC vessels, condenser, separator, and inline stack PID)	1	$ 750,000	/LS	$ 750,000	3
	Interconnecting Piping (20% of Steam-Regen Carbon System cost)	1	$ 150,000	/LS	$ 150,000	
	5000-lb Polishing Vapor-Phase GAC Vessel	2	$ 16,000	/Each	$ 32,000	4
	Orifice Plate and Transmitter	2	$ 10,000	/Each	$ 20,000	
	1000 SCFM Liquid Ring Vacuum Blower (standard cast iron construction)	2	$ 80,000	/Each	$ 160,000	5
	Moisture Separator	1	$ 4,000	/Each	$ 4,000	6
	500-Gallon Collection Tank	1	$ 2,078	/Each	$ 2,078	1
	Transfer Pump (50 gpm)	9	$ 536	/Each	$ 4,820	7
	Total for Vapor Treatment				**$ 1,150,922**	
2	**Groundwater Exraction and Treatment**					
a	Shell and Tube Heat Exchanger	1	$ 22,112	/Each	$ 22,112	8
b	DNAPL/Water Separator	2	$ 56,450	/Each	$ 112,900	9
c	Groundwater Holding Tank	1	$ 50,000	/Each	$ 50,000	
d	Two 3,000-lb Liquid-Phase GAC Vessels Each w/Initial Virgin Coconut Shell GAC Fill	1	$ 16,830	LS	$ 16,830	10
e	Air Compressor	1	$ 20,000	/Each	$ 20,000	11
f	500-Gallon Collection Tank	1	$ 2,078	/Each	$ 2,078	1
g	Cooling Tower (540 gpm Recirculation Rate)	1	$ 37,713	/Each	$ 37,713	12
h	Transfer Pump (50 gpm)	8	$ 536	/Each	$ 4,284	7
i	Transfer Pump (540 gpm)	2	$ 2,756	/Each	$ 5,513	13
j	Transfer Pump (145 gpm)	2	$ 1,348	/Each	$ 2,696	7
k	HiPOx System (100 gpm)	1	$ 1,025,000	/Each	$ 1,025,000	14
	Total for Groundwater Exraction and Treatment Equipment				**$ 1,299,126**	
3	**Equipment Pads and Containment**	1	$ 150,000	/LS	**$ 150,000**	11
4	**80' X 110' Treatment Plant Building**	1	$ 150,000	/LS	**$ 150,000**	
5	**Subcontractor Installation Cost**	1	$ 365,000	/LS	**$ 365,000**	15
	TOTAL TREATMENT EQUIPMENT INSTALLATION COST w/10% MARKUP				**$ 3,426,553**	

Cost Source Reference

1 Harrington Plastic Catalog Price
2 Heat Exchanger Sales and Engineering Company, LLC Quote Dated July 17, 2008
3 MEGTEC Systems, Inc. Quote Dated April 20, 2008
4 BakerCorp Quote Dated July 1, 2008
5 Yardley Pump and Vacuum Quote Dated July 18, 2008
6 Verbal Qoute from Enviro Supply and Services
7 Grainger Catalog Price
8 SEC Heat Exchanger Quote Dated July 1, 2008
9 Pan America Environmental Quote Dated July 28, 2008
10 BakerCorp Quoted Dated July 23, 2008
11 McMillan-McGee November 2006 Feasibility Study for Steam Injection, Page 34
12 Cooling Tower Systems Quote Dated July 2, 2008
13 McMaster-Carr Catalog Price
14 Unit Price scaled down to a 100 gpm system from $2,050,000 quote from Applied Process Technologies (June 6, 2006) for a 200 gpm system.
15 Verbal Quote from J.C. Palomar Construction, Inc.

Appendix J
Table 8.6
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Construction Management

Item	Consultant Labor	Quantity	Unit Cost		Cost
1	Project Manager	165	$ 150	/Hour	$ 24,750
2	Senior Engineer/Geologist	320	$ 125	/Hour	$ 40,000
3	Mid-Level Engineer/Geologist	880	$ 100	/Hour	$ 88,000
4	Junior/Field Engineer/Geologist	1,120	$ 75	/Hour	$ 84,000
5	Field Technician	1,120	$ 75	/Hour	$ 84,000
6	Clerical/Drafting	130	$ 50	/Hour	$ 6,500
	TOTAL CONSTRUCTION MANAGEMENT COST				$ 327,250

Appendix J
Table 8.7
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Hot Floor Pre-Heat

Item	Consultant Labor (Operations)	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	40	$ 150	/Hour	$ 6,000	
2	Senior Engineer/Geologist	40	$ 125	/Hour	$ 5,000	
3	Mid-Level Engineer/Geologist (One Full Time Mid-Level Engineer)	160	$ 100	/Hour	$ 16,000	
4	Junior/Field Engineer/Geologist (One Full Time Junior Engineer)	160	$ 75	/Hour	$ 12,000	
5	Field Technician (Three Full Time Operators - 40 Hours per Week Each)	480	$ 75	/Hour	$ 36,000	
6	Clerical/Drafting	40	$ 50	/Hour	$ 2,000	
	Consultant Labor Cost for Operations				$ 77,000	

Item	Consultant Labor (Reporting, H&S, Data Mngt, and Website Maintenance)	Quantity	Unit Cost		Cost	Cost Ref.
7	Project Manager	8	$ 150	/Hour	$ 1,200	
8	Senior Engineer/Geologist	8	$ 125	/Hour	$ 1,000	
9	Mid-Level Engineer/Geologist	62	$ 100	/Hour	$ 6,240	
10	Junior/Field Engineer/Geologist	160	$ 75	/Hour	$ 12,000	
11	Field Technician	0	$ 75	/Hour	$ -	
12	Clerical/Drafting	20	$ 50	/Hour	$ 1,000	
	Consultant labor for Reporting, H&S, Data Mngt, and Website Maintenance				$ 21,440	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
13	**Equipment Rentals**					
a	29-million BTUs/hr Low NOx Steam Generator (incl. water softening package)	1	$ 70,000	/Month	$ 70,000	1
b	8-million BTUs/hr Low Nox Steam Generator (incl. water softening package)	0	$ 15,000	/Month	$ -	2
	Total Equipment Rentals				$ 70,000	
14	**Consumables (Excluding Utilities)**					
a	Salt for Steam Generator Feed Water Treatment	4	$ 330	/Week	$ 1,320	
b	Virgin Coconut Shell Vapor-Phase Carbon	0	$ 1.07	/lb	$ -	3
c	Vapor-Phase Carbon Change-Out Service	0	$ 1,850	/Change-Out	$ -	3
d	Hydrogen Peroxide for HiPOx	3,472	$ 3.00	/Gal	$ 10,416	
e	Oxygen for HiPOx	24,273	$ 0.35	/100 SCF	$ 8,496	
f	3000-lb Liquid-Phase Carbon Change-Out (Includes T&D as Hazardous Waste)	1	$ 6,746	/Each	$ 6,746	4
	Total Consumables				$ 26,977	

Appendix J
Table 8.7
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Hot Floor Pre-Heat

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
15		**Waste Management**					
	a	Vapor-Phase GAC Disposal (Listed Waste for Incineration)	0	$ 0.71	/lb	$ -	5
	b	Vapor-Phase GAC Transportation	0	$ 4,286	/Load	$ -	5
	c	Carbon Regen System Solvent Waste Disposal (Listed Waste for Incineration)	0	$ 0.50	/lb	$ -	6
	d	Carbon Regen System Solvent Waste Transportation	0	$ 3,650	/Load	$ -	6
	e	Filtration Generated Waste Disposal (Listed Waste for Incineration)	901	$ 0.25	/lb	$ 225	6
	f	Filtration Generated Waste Transportation (filtration waste generated during hot floor pre-heat will be transported during O&M)	0	$ 2,800	/Load	$ -	6
	g	Boiler Water Pre-Treatment Brine and Blowdown Off-Site Disposal (non-Haz)	86,475	$ 0.14	/Gal	$ 12,106	7
	h	Boiler Water Pre-Treatment Brine and Blowdown Transportation	9	$ 950	/10,000 Gals	$ 8,550	7
		Total Waste Management				**$ 20,882**	
16		**Lab Analytical and Monitoring**					
	a	Summa Can Rental	13	$ 40	/Each	$ 520	8
	b	Vapor Analysis - VOCs (EPA Method TO-15)	13	$ 200	/Each	$ 2,600	8
	c	Water Analysis - Pesticides (EPA Method 8081A)	13	$ 90	/Each	$ 1,170	9
	d	Water Analysis - VOCs (EPA Method 8260B)	13	$ 95	/Each	$ 1,235	9
	e	Water Analysis - pCBSA (Modifed EPA Method 314.0)	2	$ 80	/Each	$ 160	9
	f	Tedlar Bags	20	$ 10	/Each	$ 200	
	g	TVA-1000B PID/FID Rental	1	$ 1,200	/Month	$ 1,200	10
		Total Lab Analytical and Monitoring				**$ 7,085**	
17		**Miscellaneous**					
	a	Temporary Office 24'x60' Delivery and Setup	1	$ 2,939	/Each	$ 2,939	11
	b	Temporary Office 24'x60' Rental	1	$ 1,030	/Month	$ 1,030	11
	c	Temporary Office 24'x60' Demobilization	0	$ 1,746	/Each	$ -	11
	d	Temporary Storage Trailer	1	$ 149	/Month	$ 149	12
	e	Portable Toilet Delivery	1	$ 22	/Each	$ 22	13
	f	Portable Toilet Rental	1	$ 76	/Month	$ 76	13
	g	Standby Generator (800 kW)	1	$ 8,775	/Month	$ 8,775	14
	h	Maintenance Parts	1	$ 1,000	/Month	$ 1,000	
	i	Fed Ex and Deliveries	20	$ 150	/Day	$ 3,000	
	j	Temporary office comm. (internet, telephone, fax)	1	$ 1,000	/Month	$ 1,000	
	k	Operator Truck Usage (One Truck per Operator)	20	$ 100	/Day/Truck	$ 2,000	
		Total Miscellaneous				**$ 19,989**	

Appendix J
Table 8.7
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Hot Floor Pre-Heat

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
18	Steam License for Hot Floor	25,711	$ 0.50	/CY Treated	$ 12,856	15
	Total Subcontractor Cost				$ 157,789	

Item	Utilities	Quantity	Unit Cost		Cost	Cost Ref.
19	Electricity Usage	211,420	$ 0.1045	/kWh	$ 22,093	16
20	Natural Gas for Steam Generation	199,901	$ 1.14	/Therm	$ 227,888	17
21	Municipal Water for Cooling Tower Makeup	219,000	$ 0.0029	/Gal	$ 635	
22	Municipal Water for Steam Generation	1,121,152	$ 0.0029	/Gal	$ 3,251	
	Total Utilities				$ 253,867	

CONSULTANT LABOR COST	$ 98,440
SUBCONTRACTOR COST w/10% MARKUP	$ 173,567
UTILITIES COST (NO MARKUP)	$ 253,867
TOTAL COST FOR HOT FLOOR PRE-HEAT	$ 525,875

Cost Source Reference

1 Nationwide Boiler Quote Dated May 16, 2008
2 Nationwide Boiler Quote Dated July 30, 2008
3 BakerCorp Quote Dated June 30, 2008
4 BakerCorp Quote July 23, 2008
5 NRC Environmental Services, Inc. Quote Dated June 30, 2008
6 Clean Harbors Quote Dated October 10, 2007
7 NRC Environmental Services, Inc. Email Quote Dated July 18, 2008
8 Verbal Quote from Calscience Environmental Laboratories, Inc.
9 Verbal Quote from Test America
10 Verbal Quote from Ashtead Technology Rentals
11 Mobile Mini, Inc. Quote Dated October 11, 2007
12 Verbal Quote from Mobile Mini, Inc.
13 Verbal Quote from A-1 Coast Port-A-Toilet
14 Kohler Rental Quote Dated June 30, 2008
15 McMillan-McGee November 2006 Feasibility Study for Steam Injection, Page 33
16 Shedule A-3 LADWP Rate (Second Quarter 2008)
17 GN-10, Tier III, SoCal Gas Co. Rate (Effective May 1, 2008)

Appendix J
Table 8.8
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Operations and Maintenance

Item	Consultant Labor (Operations)	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	520	$ 150	/Hour	$ 78,000	
2	Senior Engineer/Geologist	520	$ 125	/Hour	$ 65,000	
3	Mid-Level Engineer/Geologist (One Full Time Mid-Level Engineer)	2,080	$ 100	/Hour	$ 208,000	
4	Junior/Field Engineer/Geologist (One Full Time Junior Engineer)	2,080	$ 75	/Hour	$ 156,000	
5	Field Technician (Three Full Time Operators - 40 Hours per Week Each)	6,240	$ 75	/Hour	$ 468,000	
6	Clerical/Drafting	520	$ 50	/Hour	$ 26,000	
	Consultant Labor Cost for Operations				**$ 1,001,000**	

Item	Consultant Labor (Reporting, H&S, Data Mngt, and Website Maintenance)	Quantity	Unit Cost		Cost	Cost Ref.
7	Project Manager	20	$ 150	/Hour	$ 3,000	
8	Senior Engineer/Geologist	80	$ 125	/Hour	$ 10,000	
9	Mid-Level Engineer/Geologist	1,300	$ 100	/Hour	$ 130,000	
10	Junior/Field Engineer/Geologist	2,080	$ 75	/Hour	$ 156,000	
11	Field Technician	0	$ 75	/Hour	$ -	
12	Clerical/Drafting	180	$ 50	/Hour	$ 9,000	
	Consultant labor for Reporting, H&S, Data Mngt, and Website Maintenance				**$ 308,000**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
13	**Equipment Rentals**					
a	29-million BTUs/hr Low NOx Steam Generator (incl. water softening package)	12	$ 70,000	/Month	$ 840,000	1
b	8-million BTUs/hr Low Nox Steam Generator (incl. water softening package)	12	$ 15,000	/Month	$ 180,000	2
	Total Equipment Rentals				**$ 1,020,000**	
14	**Consumables (Excluding Utilities)**					
a	Salt for Steam Generator Feed Water Treatment	51	$ 425	/Week	$ 21,616	
b	Virgin Coconut Shell Vapor-Phase Carbon (7,000-lbs of polishing GAC per month plus 10,000 lbs of regen system carbon changed-out after six months)	94,000	$ 1.07	/lb	$ 100,580	3
c	Vapor-Phase Carbon Change-Out Service	10	$ 1,739	/Change-Out	$ 17,390	3
d	Hydrogen Peroxide for HiPOx	166,650	$ 3.00	/Gal	$ 499,950	
e	Oxygen for HiPOx	1,165,100	$ 0.35	/100 SCF	$ 407,785	
f	3000-lb Liquid-Phase Carbon Change-Out (Includes T&D as Hazardous Waste)	48	$ 6,746	/Each	$ 323,808	4
	Total Consumables				**$ 1,371,129**	

Appendix J
Table 8.8
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Operations and Maintenance

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
15		**Waste Management**					
	a	Vapor-Phase GAC Disposal (Listed Waste for Incineration) (incl. 10,000 lbs of regen system carbon at year end)	80,000	$ 0.71	/lb	$ 56,800	5
	b	Vapor-Phase GAC Transportation	5	$ 4,286	/Load	$ 21,430	5
	c	Carbon Regen System Solvent Waste Disposal (Listed Waste for Incineration)	169,000	$ 0.50	/lb	$ 84,500	6
	d	Carbon Regen System Solvent Waste Transportation	5	$ 3,650	/Load	$ 18,250	6
	e	Filtration Generated Waste Disposal (Listed Waste for Incineration)	39,300	$ 0.25	/lb	$ 9,825	6
	f	Filtration Generated Waste Transportation	4	$ 2,800	/Load	$ 11,200	6
	g	Boiler Water Pre-Treatment Brine and Blowdown Off-Site Disposal (non-Haz)	1,371,164	$ 0.14	/Gal	$ 191,963	7
	h	Boiler Water Pre-Treatment Brine and Blowdown Transportation	138	$ 950	/10,000 Gals	$ 131,100	7
		Total Waste Management				**$ 525,068**	
16		**Lab Analytical and Monitoring**					
	a	Summa Can Rental	176	$ 40	/Each	$ 7,040	8
	b	Vapor VOCs Analysis (EPA Method TO-15)	176	$ 200	/Each	$ 35,200	8
	c	Liquid Pesticides (EPA Method 8260B)	176	$ 90	/Each	$ 15,840	9
	d	Liquid VOC Analysis (EPA Method 8081A)	176	$ 95	/Each	$ 16,720	9
	e	Liquid pCBSA Analysis (Modifed EPA Method 314.0)	24	$ 80	/Each	$ 1,920	9
	f	Tedlar Bags	240	$ 10	/Each	$ 2,400	
	g	TVA-1000B PID/FID Rental	12	$ 1,200	/Month	$ 14,400	10
		Total Lab Analytical and Monitoring				**$ 93,520**	

Appendix J
Table 8.8
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Operations and Maintenance

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
17		**Miscellaneous**					
	a	Temporary Office 24'x60' Delivery and Setup	0	$ 2,939	/Each	$ -	11
	b	Temporary Office 24'x60' Rental	12	$ 1,030	/Month	$ 12,356	11
	c	Temporary Office 24'x60' Demobilization	1	$ 1,746	/Each	$ 1,746	11
	d	Temporary Storage Trailer	12	$ 149	/Month	$ 1,784	12
	e	Portable Toilet Delivery	0	$ 22	/Each	$ -	13
	f	Portable Toilet Rental	12	$ 76	/Month	$ 908	13
	g	Standby Generator (800 kW)	12	$ 8,775	/Month	$ 105,300	14
	h	Maintenance Parts	12	$ 1,000	/Month	$ 12,000	
	i	Fed Ex and Deliveries	260	$ 150	/Day	$ 39,000	
	j	Temporary office comm. (internet, telephone, fax)	12	$ 1,000	/Month	$ 12,000	
	k	Operator Truck Usage (One Truck per Operator)	520	$ 100	/Day/Truck	$ 52,000	
		Total Miscellaneous				**$ 237,094**	
18		**Steam License for UBA**	57,665	$ 0.50	/CY Treated	**$ 28,833**	15
		Total Subcontractor Cost (O&M Year 1)				**$ 3,275,643**	

Item	Utilities	Quantity	Unit Cost		Cost	Cost Ref.
19	Electricity Usage	10,148,151	$ 0.1045	/kWh	$ 1,060,482	16
20	Natural Gas for Steam Generation	3,095,223	$ 1.14	/Therm	$ 3,528,554	17
21	Municipal Water for Cooling Tower Makeup	2,628,000	$ 0.0029	/Gal		
22	Municipal Water for Steam Generation	18,180,972	$ 0.0029	/Gal	$ 52,725	
	Total Utilities				**$ 4,641,761**	

FULL SCALE CONSULTANT LABOR COST	**$ 1,309,000**
FULL SCALE SUBCONTRACTOR COST w/10% MARKUP	**$ 3,603,208**
UTILITIES COST (NO MARKUP)	**$ 4,641,761**
TOTAL OPERATIONS AND MAINTENANCE COST	**$ 9,553,968**

Appendix J
Table 8.8
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Operations and Maintenance

Cost Source Reference

1 Nationwide Boiler Quote Dated May 16, 2008
2 Nationwide Boiler Quote Dated July 30, 2008
3 BakerCorp Quote Dated June 30, 2008. Unit price for carbon change-out services is scaled down for a 9,400-lb change-out from BakerCorp quote of $1,850 per change-out for 10,000 lbs.
4 BakerCorp Quote July 23, 2008
5 NRC Environmental Services, Inc. Quote Dated June 30, 2008
6 Clean Harbors Quote Dated October 10, 2007
7 NRC Environmental Services, Inc. Email Quote Dated July 18, 2008
8 Verbal Quote from Calscience Environmental Laboratories, Inc.
9 Verbal Quote from Test America
10 Verbal Quote from Ashtead Technology Rentals
11 Mobile Mini, Inc. Quote Dated October 11, 2007
12 Verbal Quote from Mobile Mini, Inc.
13 Verbal Quote from A-1 Coast Port-A-Toilet
14 Kohler Rental Quote Dated June 30, 2008
15 McMillan-McGee November 2006 Feasibility Study for Steam Injection, Page 33
16 Shedule A-3 LADWP Rate (Second Quarter 2008)
17 GN-10, Tier III, SoCal Gas Co. Rate (Effective May 1, 2008)

Appendix J
Table 8.9
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Well Abandonment

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	50	$ 150	/Hour	$ 7,500	
2	Senior Engineer/Geologist	232	$ 125	/Hour	$ 29,000	
3	Mid-Level Engineer/Geologist	125	$ 100	/Hour	$ 12,500	
4	Junior/Field Engineer/Geologist	1,184	$ 75	/Hour	$ 88,800	
5	Field Technician	50	$ 75	/Hour	$ 3,750	
6	Clerical/Drafting	50	$ 50	/Hour	$ 2,500	
	Total Consultant Labor Cost				$ 144,050	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
1	**Mobilization/Demobilization of Drill Rig**	1	$ 2,000	/LS	**$ 2,000**	1
2	**Abandon UBA Multi-Phase Extraction Wells**					
a	Drill out well materials	105	$ 65	/Foot	$ 6,825	1
b	Grout resulting boring	105	$ 30	/Foot	$ 3,150	1
c	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
d	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
e	Vehicle Usage	1	$ 100	/Day	$ 100	
f	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
g	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 11,075	
	Number of Wells				27	
	Total for UBA Multi-Phase Extraction Well Adandonment				**299,025**	
3	**Abandon Triple-Nested UBA Steam Injecton Wells**					
a	Drill out well materials	60	$ 65	/Foot	$ 3,900	1
b	Grout resulting boring	60	$ 30	/Foot	$ 1,800	1
c	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
d	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
e	Vehicle Usage	1	$ 100	/Day	$ 100	
f	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
g	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 6,800	
	Number of Wells				14	
	Total for UBA Triple-Nested Steam Injection Well Abandonment				**95,200**	
4	**Abandon Hot Floor Multi-Phase Extraction Wells**					
a	Pressure grout well	105	$ 30	/Foot	$ 3,150	1
b	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
c	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
f	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 4,250	
	Number of Wells				10	
	Total for Hot Floor Multi-Phase Extraction Well Abandonment				**$ 42,500**	
5	**Abandon Hot Floor Steam Injection Wells**					
a	Pressure grout well	105	$ 30	/Foot	$ 3,150	1
b	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
c	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
f	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 4,250	
	Number of Wells				26	
	Total for Hot Floor Steam Injection Well Abandonment				**$ 110,500**	

Appendix J
Table 8.9
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Well Abandonment

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
6	**Abandon Temperature Monitoring Points**					
a	Pressure grout well	105	$ 30	/Foot	$ 3,150	1
b	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
c	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
f	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 4,250	
	Number of Wells				14	
	Total for Temperature Monitoring Point Abandonment				$ 59,500	
7	**Waste Management**					
a	Waste Tank Rental	0	$ 38	/Day	$ -	
b	Waste Tank Rental Delivery - Mob and Demob	0	$ 900	/Each	$ -	
c	Waste Bin Rental	540	$ 15	/Day	$ 8,100	2
d	Waste Bin Rental Delivery - Mob and Demob	18	$ 500	/Each	$ 9,000	2
e	Transport of Hazardous Soil Cuttings	18	$ 1,100	/Each	$ 19,800	2
f	Disposal of Hazardous Soil Cuttings	269	$ 550	/Ton	$ 147,950	2
g	Transport of Hazardous Mud	0	$ 500	/Each	$ -	
h	Disposal of Hazardous Mud	0	$ 1.1	/Gal	$ -	
i	Transport of Hazardous Water	1	$ 1,100	/Each	$ 1,100	2
j	Disposal of Hazardous Water	1982	$ 0.8	/Gal	$ 1,586	2
k	Waste Characterization/Profiling	2	$ 500	/Each	$ 1,000	
	Total Waste Management				$ 188,536	
	Total Subcontractor Cost w/10% Markup				$ 876,987	

TOTAL WELL ABANDONMENT COST	$ 1,021,037

Cost Source Reference

1. Verbal Quote from Water Development Corporation.
2. Verbal Quote from NRC Environmental Services

Appendix J
Table 8.10
Detailed Cost, Steam Injection (3 UBA PVs and 3.5 Hot Floor PVs)
Demobilization

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	60	$ 150	/Hour	$ 9,000	
2	Senior Engineer/Geologist	200	$ 125	/Hour	$ 25,000	
3	Mid-Level Engineer/Geologist	654	$ 100	/Hour	$ 65,400	
4	Junior/Field Engineer/Geologist	800	$ 75	/Hour	$ 60,000	
5	Field Technician	425	$ 75	/Hour	$ 31,875	
6	Clerical/Drafting	140	$ 50	/Hour	$ 7,000	
	Consultant Labor Cost				**$ 198,275**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Remove Purchased Treatment Equipment**	1	$ 317,000	/LS	**$ 317,000**	
8	**Close-Out Borings**					
a	Drilling	9	$ 12,000	/Boring	$ 108,000	1
b	Waste Disposal	9	$ 5,500	/Boring	$ 49,500	2
c	Soil Pesticides (EPA Method 8081A)	54	$ 90	/Sample	$ 4,860	3
d	Soil VOCs (EPA Method 8260B)	54	$ 95	/Sample	$ 5,130	3
e	Soil pCBSA (Modified EPA Method 314.0)	54	$ 80	/Sample	$ 4,320	3
f	Liquid Pesticides (EPA Method 8081A)	9	$ 90	/Sample	$ 810	3
g	Liquid VOCs (EPA Method 8260B)	9	$ 95	/Sample	$ 855	3
h	Liquid pCBSA (Modified EPA Method 314.0)	9	$ 80	/Sample	$ 720	3
	Total for Close-Out Borings				**$ 174,195**	
	Total Subcontractor Cost w/10% Markup				**$ 540,315**	

	TOTAL DEMOBILIZATION COST	**$ 738,590**

Cost Source Reference
1 Verbal Quote from Water Development Corporation
2 Verbal Quote from NRC Environmental Services
3 Verbal Quote from Test America

Appendix J
Table 9.0
Cost Summary
ERH
Focused Treatment Area

Discount Rate 4%

Year	Activity	Detailed Cost Table	Cost (Undiscounted)	Cost (NPV)
1	Focused Treatment Design	J-9.1 Design and Permitting Cost	$ 1,160,300	$ 1,115,673
2	Focused Treatment Build	J-9.2 Well Construction	$ 3,996,515	$ 9,050,943
		J-9.3 Well Field Equipment Installation	$ 2,170,154	
		J-9.4 Instrumentation and Controls Installation	$ 64,124	
		J-9.5 Treatment Equipment Installation	$ 3,160,979	
		J-9.6 Construction Management	$ 397,728	
3	Focused Treatment Operation and Maintenance	J-9.7 Operations and Maintenance	$ 6,063,104	$ 5,390,077
4	Verification and Abandonment	J-9.8 Well Abandonment	$ 1,411,846	$ 1,819,759
		J-9.9 Demobilization	$ 717,015	

Total NPV at 4 Years	**$ 17,376,453**
Total Undiscounted Cost	**$ 19,141,765**

BOE-C6-0060241

Appendix J
Table 9.1
Detailed Cost, ERH
Design and Permitting

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	790	$ 150	/Hour	$ 118,500	
2	Senior Engineer/Geologist	1,170	$ 125	/Hour	$ 146,250	
3	Mid-Level Engineer/Geologist	4,600	$ 100	/Hour	$ 460,000	
4	Junior/Field Engineer/Geologist	3,310	$ 75	/Hour	$ 248,250	
5	Field Technician	0	$ 75	/Hour	$ -	
6	Clerical/Drafting	1,106	$ 50	/Hour	$ 55,300	
	Consultant Labor				**$ 1,028,300**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
1	**Outside Thermal Expert**	1	$ 120,000	/LS	**$ 120,000**	
	Subcontractor Cost w/10% Markup				**$ 132,000**	

	TOTAL DESIGN AND PERMITTING COST	**$ 1,160,300**

Appendix J
Table 9.2
Detailed Cost, ERH (No Hot Floor)
Well Construction

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	507	$ 150	/Hour	$ 76,050	
2	Senior Engineer/Geologist	507	$ 125	/Hour	$ 63,375	
3	Mid-Level Engineer/Geologist	1,352	$ 100	/Hour	$ 135,200	
4	Junior/Field Engineer/Geologist	3,050	$ 75	/Hour	$ 228,750	
5	Field Technician	482	$ 75	/Hour	$ 36,150	
6	Clerical/Drafting	507	$ 50	/Hour	$ 25,350	
	Total Consultant Labor Cost				**$ 564,875**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Abandon Existing Site Wells Prior to Thermal Treatment**					
a	Drill out well materials	90	$ 65	/Foot	$ 5,850	1
b	Grout resulting boring	90	$ 30	/Foot	$ 2,700	1
c	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
d	Excavate and remove well box	1	$ 2,000	/LS	$ 2,000	1
e	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
f	Vehicle Usage	1	$ 100	/Day	$ 100	
g	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
h	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 11,650	
	Number of Wells				5	
	Total for Existing Site Well Abandonment				**$ 58,250**	

BOE-C6-0060243

Appendix J
Table 9.2
Detailed Cost, ERH (No Hot Floor)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
8	**UBA Multi-Phase Extraction Wells (12" HSA Drilling to 108' bgs)**					
a	Install Well Constructed of 6" LCS Casing w/ 60' of SS Screen and 3-foot Sump, Type II Cement Grout, and Sand Pack	1	$ 12,000	/Each	$ 12,000	2
b	Forklift and Hopper Rental for Waste Handling	1	$ 250	/Day	$ 250	2
c	Drill Crew per Diem	1	$ 450	/Night	$ 450	2
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
f	Installation Permit	1	$ 201	/Well	$ 201	
g	Other Direct Costs	1	$ 300	/Day	$ 300	
	Cost per Well				$ 13,801	
	Number of Wells (1 Well Installed per Day)				66	
	Subtotal - UBA Multi-Phase Extraction Wells				**$ 910,866**	
9	**Lab Analytical (Sixteen UBA Multi-Phase Extraction Well Borings)**					
a	Soil Analysis - Pesticides (EPA Method 8081A)	54	$ 90	/Sample	$ 4,860	3
b	Soil Analysis - VOCs (EPA Method 8260B)	54	$ 95	/Sample	$ 5,130	3
c	Soil Analysis - pCBSA (Modified EPA Method 314.0)	54	$ 80	/Sample	$ 4,320	3
d	Water Analysis - Pesticides (EPA Method 8081A)	9	$ 90	/Sample	$ 810	3
e	Water Analysis - VOCs (EPA Method 8260B)	9	$ 95	/Sample	$ 855	3
f	Water Analysis - pCBSA (Modified EPA Method 314.0)	9	$ 80	/Sample	$ 720	3
	Total Lab Analytical (UBA Extraction Wells)				**$ 16,695**	

BOE-C6-0060244

Appendix J
Table 9.2
Detailed Cost, ERH (No Hot Floor)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
10	**Electrode Wells (15" HSA Drilling to 105' bgs)**					
a	Drill Rig, Crew, and Support Equipment	1	$ 4,000	/Each	$ 4,000	4
b	Cement Backfill Material	54	$ 30	/Foot	$ 1,620	4
c	Sand Backfill Material	51	$ 20	/Foot	$ 1,020	4
d	Drill Crew per Diem	1	$ 450	/Night	$ 450	4
e	Forklift and Hopper Rental for Waste Handling	1	$ 250	/Day	$ 250	4
f	Plastic Sheeting and Hole Prep	1	$ 25	/Well	$ 25	4
g	5% Fuel Surcharge	1	$ 368	/Day	$ 368	4
h	Vehicle Usage	1	$ 100	/Day	$ 100	
i	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
j	Installation Permit	1	$ 201	/Well	$ 201	
k	Other Direct Costs	1	$ 300	/Day	$ 300	
	Cost per Well				$ 8,834	
	Number of Wells (1 Well Installed per Day)				102	
	Subtotal - Electrode Wells				**$ 901,094**	
11	**Develop UBA Multi-Phase Extraction Wells**					
a	Development Rig	1	$ 2,000	/Day	$ 2,000	2
b	Development Crew per Diem	1	$ 200	/Night	$ 200	2
	Cost per Well				$ 2,200	
	Number of Wells (1 Well Developed per Day)				66	
	Subtotal - Develop UBA Wells				**$ 145,200**	

Appendix J
Table 9.2
Detailed Cost, ERH (No Hot Floor)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
12	**Mobilization/Demobilization of Mud Rotary Drill Rig**	1	$ 12,000	/Each	**$ 12,000**	4
13	**Hot Floor Multi-Phase Extraction Wells**					
a	Move Between Well Locations	1	$ 2,000	/Each	$ 2,000	5
b	Install 14", .25" Wall, Low Carbon Steel Conductor Casing with Type II Cement Grout	110	$ 220	/Foot	$ 24,200	5
c	Mud Change-Out and Pit Decon	1	$ 2,000	/Each	$ 2,000	5
d	12" Boring Under Conductor	8.5	$ 80	/Foot	$ 680	5
e	Install 6" Low Carbon Steel Sched. 40 Casing	110.5	$ 88	/Foot	$ 9,724	5
f	Install 6" Type 304 Stainless Steel Screen with 3' Sump	8	$ 175	/Foot	$ 1,400	5
g	Type II Cement Grout and Sand Pack	118.5	$ 30	/Foot	$ 3,555	5
h	Forklift and Hopper Rental for Waste Handling	4	$ 400	/Day	$ 1,600	5
i	Standby for Cement Curing	6	$ 550	/Hour	$ 3,300	5
j	Well Development	10	$ 165	/Hour	$ 1,650	5
k	Vehicle Usage	4	$ 100	/Day	$ 400	
l	Equipment Rental and Supplies	4	$ 500	/Day	$ 2,000	
m	Installation Permit	1	$ 201	/Well	$ 201	
n	Other Direct Costs	4	$ 300	/Day	$ 1,200	
	Cost per Well				$ 53,910	
	Number of Wells (4 Days per Well for Installation and Development)				0	
	Subtotal - Hot Floor Multi-Phase Extraction Wells				**$ -**	

Appendix J
Table 9.2
Detailed Cost, ERH (No Hot Floor)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost			Cost	Cost Ref.
14	**Hot Floor Steam Injecton Wells**						
a	Move Between Well Locations	1	$	2,000	/Each	$ 2,000	5
b	Install 10", .25" Wall, Low Carbon Steel Conductor Casing with Type II Cement Grout	110	$	180	/Foot	$ 19,800	5
c	Mud Change-Out	1	$	1,500	/Each	$ 1,500	5
d	9" Boring Under Conductor	5.5	$	75	/Foot	$ 413	5
e	Install 2" Low Carbon Steel Sched. 40 Casing	110.5	$	45	/Foot	$ 4,973	5
f	Install 2" Type 304 Stainless Steel Screen	5	$	90	/Foot	$ 450	5
g	Type II Cement Grout and Sand Pack	115.5	$	20	/Foot	$ 2,310	5
h	Forklift and Hopper Rental for Waste Handling	4	$	400	/Day	$ 1,600	5
i	Standby for Cement Curing	5	$	550	/Hour	$ 2,750	5
j	Well Development	6	$	165	/Hour	$ 990	5
k	Vehicle Usage	4	$	100	/Day	$ 400	
l	Equipment Rental and Supplies	4	$	500	/Day	$ 2,000	
m	Installation Permit	1	$	201	/Well	$ 201	
n	Other Direct Costs	4	$	300	/Day	$ 1,200	
	Cost per Well					$ 40,586	
	Number of Wells (4 Days per Well for Installation and Development)					0	
	Subtotal - Hot Floor Steam Injecton Wells					$ -	

BOE-C6-0060247

Appendix J
Table 9.2
Detailed Cost, ERH (No Hot Floor)
Well Construction

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
15		**Temperature Monitoring Points (7" HAS Drilling to 105' bgs)**					
	a	Move Between Well Locations	1	$ 4,000	/Each	$ 4,000	
	b	Install 10", .25 Wall, Low Carbon Steel Conductor Casing with Type II Cement Grout	0	$ 180	/Foot	$ -	
	c	Mud Change-Out	0	$ 1,500	/Each	$ -	
	d	8" Boring Under Conductor	0	$ 75	/Foot	$ -	
	e	Install 1.5" Low Carbon Steel Casing with Bottom Cap	105	$ 40	/Foot	$ 4,200	
	f	Type II Cement Grout	105	$ 20	/Foot	$ 2,100	
	g	Forklift and Hopper Rental for Waste Handling	1	$ 250	/Day	$ 250	
	h	Standby for Cement Curing	0	$ 550	/Hour	$ -	
	i	Vehicle Usage	1	$ 100	/Day	$ 100	
	j	Equipment Rental and Supplies	1	$ 500	/Day	$ 500	
	k	Installation Permit	1	$ 201	/Well	$ 201	
	i	Other Direct Costs	1	$ 300	/Day	$ 300	
		Subtotal				$ 11,651	
		Number of Wells (3 Days per Point - no Development Needed)				14	
		Subtotal - Temperature Monitoring Points				**$ 163,114**	
16		**BFS Monitoring Wells**					
	a	Well Installation (4 Days per Well for Installation and Development)	2	$ 54,000	/Well	$ 108,000	1
	b	Installation Permit	2	$ 201	/Well	$ 402	
		Subtotal - BFS Monitoring Wells				**$ 108,402**	

Appendix J
Table 9.2
Detailed Cost, ERH (No Hot Floor)
Well Construction

Item	Subcontractor Cost	Quantity	Unit Cost			Cost	Cost Ref.
17	**Waste Management**						
a	Waste Tank Rental	290	$	38	/Day	$ 11,020	6
b	Waste Tank Rental Delivery - Mob and Demob	1	$	900	/Each	$ 900	6
c	Waste Bin Rental	1762	$	15	/Day	$ 26,430	6
d	Waste Bin Rental Delivery - Mob and Demob	58	$	500	/Each	$ 29,000	6
e	Transport of Hazardous Soil Cuttings	58	$	1,100	/Each	$ 63,800	6
f	Disposal of Hazardous Soil Cuttings	1178	$	550	/Ton	$ 647,900	6
g	Transport of Hazardous Mud	0	$	500	/Each	$ -	6
h	Disposal of Hazardous Mud	0	$	1.1	/Gal	$ -	6
i	Transport of Hazardous Water	6	$	1,100	/Each	$ 6,600	6
j	Disposal of Hazardous Water	21753	$	0.8	/Gal	$ 17,402	6
k	Waste Characterization/Profiling	2	$	500	/Each	$ 1,000	
	Subtotal - Waste Management					**$ 804,052**	
	Total Subcontractor Cost w/10% Markup					**$ 3,431,640**	

TOTAL WELL CONSTRUCTION COST	**$ 3,996,515**

Cost Source Reference

1 Verbal Quote from Water Development Corporation
2 Cascade Drilling, Inc. Quote Dated 7/15/08
3 Verbal Quote from Test America
4 Cascade Drilling, Inc. Quote Dated 8/01/08
5 Water Development Corporation Quote Dated 4/25/08
6 Verbal Quote from NRC Environmental

Appendix J
Table 9.3
Detailed Cost, ERH
Well Field Equipment Installation

Item		Consultant Labor and Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
1		**Electrical Service Upgrade**	1	$ 50,000	LS	$ 50,000	
2		**Natural Gas Pipeline**	1	$ 200,000	LS	$ 200,000	
3		**Electrode Well Equipment and Piping**					
	a	Electrodes (3 per Electrode Well)	306	$ 1,500	Each	$ 459,000	1
	b	Armored Electrical Cable	2380	$ 4.89	Foot	$ 11,638	2
	c	1.5-Inch Carbon Steel Pipe and Fittings for Recirc Water Delivery	2380	$ 12.00	LF	$ 28,560	
		Total Electrode Well Equipment				$ 499,198	
4		**Groundwater Extraction Assemblies**					
	a	Well Head Assemblies	66	$ 1,000	Each	$ 66,000	
	b	Extraction Pump (High Temperature Hammerhead Pro)	66	$ 3,070	Each	$ 202,620	3
	c	Downwell Air Supply Hose (3/8" SS Brainded, Teflon Lined)	6600	$ 11	LF	$ 72,600	3
	d	Downwell Air Exhaust Hose (1/2" SS Brainded, Teflon Lined)	6600	$ 16	LF	$ 105,600	3
	e	Downwell Discharge Hose (1/4" SS Brainded, Teflon Lined)	6600	$ 22	LF	$ 145,200	3
		Total Groundwater Extraction Assemblies				$ 592,020	
5		**Steam Injection Well Head Assemblies**	0	$ 7,000	Each	$ -	
6		**Field Technician - Pump and Well Head Assembly Construction and Installation** (Consultant Labor - Not Subject to Markup)	1,370	$ 75	Hour	$ 102,750	
7		**Steam Injection Piping**					
	a	6-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	0	$ 67.65	LF	$ -	4
	b	4-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	0	$ 43.45	LF	$ -	4
	c	2-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	0	$ 34.10	LF	$ -	4
		Total Steam Injection Piping				$ -	
8		**Vapor Extraction Piping**					
	a	8-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	605	$ 94.71	LF	$ 57,300	5
	b	6-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1810	$ 67.65	LF	$ 122,447	4
	c	4-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	677	$ 43.45	LF	$ 29,416	4
		Total Vapor Extraction Piping				$ 209,162	

Appendix J
Table 9.3
Detailed Cost, ERH
Well Field Equipment Installation

Item		Consultant Labor and Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
9		**Groundwater Extraction Piping**					
	a	4-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	605	$ 43.45	LF	$ 26,287	4
	b	2-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	1810	$ 34.10	LF	$ 61,721	4
	c	1.5-Inch Carbon Steel Pipe and Fittings (incl. Fiberglass Insulation and Aluminum Jacket)	677	$ 31.45	LF	$ 21,292	4
	d	Total Piping Length	3092		LF		
	e	Piping Heat Trace, VLBTV Wire	3092	$ 15.75	LF	$ 48,699	6
	f	Misc fittings and heat trace elements (30% of Groundwater Extraction Piping cost)	1	$ 47,399.67	LS	$ 47,400	
		Total Groundwater Extraction Piping				**$ 205,399**	
10		**Compressed Air Pipe and Fittings (2-Inch Carbon Steel)**	3092	$ 20.00	LF	**$ 61,840**	4
11		**Pipe Supports**	309.2	$ 200	LF	**$ 61,840**	
		CONSULTANT LABOR COST				**$ 102,750**	
		DIRECT COSTS w/10% MARKUP				**$ 2,067,404**	
		TOTAL WELL FIELD EQUIPMENT INSTALLTION COST				**$ 2,170,154**	

Cost Source Reference

1 Verbal Quote from McMillan-McGee Corp.
2 McMaster-Carr Catalog Price
3 QED Environmental Systems, Inc. Quote Dated May 16, 2008
4 2007 RS Means Database. Unit price shown includes 10% inflation rate and local area cost factor.
5 Unit rate assumed to be approximately 40% higher than rate for 6-inch carbon steel pipe and fittings with fiberglass insulation and aluminum jacket.
6 2006 Raychem quote obtained by CH2MHILL

Appendix J
Table 9.4
Detailed Cost, ERH
Instrumentation and Controls Installation

Item		Consultant Labor and Direct Costs	Quantity	Unit Cost		Cost	Cost Ref.
1		**Steam Injection Wells**					
	a	Pressure Gage (0-300 PSI)	0	$ 48	/Each	$ -	1
	b	Temperature Indicator	0	$ 127	/Each	$ -	1
	c	Orifice Plate and Transmitter	0	$ 10,000	/Each	$ -	
		Total Steam Injection Wells and Piping I&Cs				$ -	
2		**Groundwater Exraction Pressure Gage (0-300 PSI)**	66	$ 48	/Each	$ 3,168	1
3		**Vapor Extraction Vacuum Gage (30 in Hg)**	66	$ 50	/Each	$ 3,326	1
4		**Thermocouple String**					
	a	Type T Thermocouple Wire (24 Gauge w/Fiberglass Insulation and Jacket)	1,400	$ 0.75	/Foot	$ 1,050	2
	b	Analog Decoder	1	$ 500	/Each	$ 500	
		Cost per Temp Monitoring Point				$ 1,550	
		Number of Temperature Monitoring Points				14	
		Total Thermocouple String				21,700	
5		**Field Technician - Installation of Items 1 Through 4 (Instrumentation and Controls)** (Consultant Labor - Not Subject to Markup)	152	$ 75	/Hour	$ 11,400	
6		**Electrical Allowance (20% of Instrumentation and Controls cost)**	1	$ 8,458	/LS	$ 8,458	
7		**Control System Allowance (30% of Instrumentation and Controls cost)**	1	$ 11,278	/LS	$ 11,278	
		CONSULTANT LABOR COST				$ 11,400	
		DIRECT COSTS w/10% MARKUP				$ 52,724	
		TOTAL INSTRUMENTATION AND CONTROLS INSTALLATION COST				$ 64,124	

Cost Source Reference
1 Grainger Catalog Price
2 McMaster-Carr Catalog Price

Appendix J
Table 9.5
Detailed Cost, ERH
Treatment Equipment Installation

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
1		**Vapor Treatment**					
	a	12,000-gallon Brine Holding Tank	1	$ 18,538	/Each	$ 18,538	1
	b	Fin-Fan Heat Exchanger	1	$ 14,306	/Each	$ 14,306	2
	c	Steam-Regenerable Carbon System					
		(incl. two 5,000-lb GAC vessels, condenser, separator, and inline stack PID)	1	$ 750,000	/LS	$ 750,000	3
	d	2MM BTUs/Hr Steam Generator (Gas Fired)	1	$ 5,000	/Each	$ 5,000	
	e	Water Softening Unit for Steam Generator	1	$ 5,000	/Each	$ 5,000	
	f	Interconnecting Piping (20% of Steam-Regen Carbon System cost)	1	$ 150,000	/LS	$ 150,000	
	g	5000-lb Polishing Vapor-Phase GAC Vessel	2	$ 16,000	/Each	$ 32,000	4
	h	Orifice Plate and Transmitter	2	$ 10,000	/Each	$ 20,000	
	i	1000 SCFM Liquid Ring Vacuum Blower (standard cast iron construction)	2	$ 80,000	/Each	$ 160,000	5
	j	Moisture Separator	1	$ 4,000	/Each	$ 4,000	6
	k	500-Gallon Collection Tank	1	$ 2,078	/Each	$ 2,078	1
	l	Transfer Pump (50 gpm)	9	$ 536	/Each	$ 4,820	7
		Total for Vapor Treatment				**$ 1,165,742**	
2		**Groundwater Exraction and Treatment**					
	a	Shell and Tube Heat Exchanger	1	$ 22,112	/Each	$ 22,112	8
	b	DNAPL/Water Separator	2	$ 56,450	/Each	$ 112,900	9
	c	Groundwater Holding Tank	1	$ 50,000	/Each	$ 50,000	
	d	Two 3,000-lb Liquid-Phase GAC Vessels Each w/Initial Virgin Coconut Shell GAC Fill	1	$ 16,830	LS	$ 16,830	10
	e	Air Compressor	1	$ 20,000	/Each	$ 20,000	11
	f	500-Gallon Collection Tank	1	$ 2,078	/Each	$ 2,078	1
	g	Cooling Tower (540 gpm Recirculation Rate)	1	$ 37,713	/Each	$ 37,713	12
	h	Transfer Pump (50 gpm)	8	$ 536	/Each	$ 4,284	7
	i	Transfer Pump (540 gpm)	2	$ 2,756	/Each	$ 5,513	13
	j	Transfer Pump (145 gpm)	2	$ 1,348	/Each	$ 2,696	7
	k	HiPOx System (50 gpm)	1	$ 768,750	/Each	$ 768,750	14
		Total for Groundwater Exraction and Treatment Equipment				**$ 1,042,876**	

Appendix J
Table 9.5
Detailed Cost, ERH
Treatment Equipment Installation

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
3	**Equipment Pads and Containment**	1	$ 150,000	/LS	$ 150,000	11
4	**80' X 110' Treatment Plant Building**	1	$ 150,000	/LS	$ 150,000	
5	**Subcontractor Installation Cost**	1	$ 365,000	/LS	$ 365,000	15
	TOTAL TREATMENT EQUIPMENT INSTALLATION COST w/10% MARKUP				$ 3,160,979	

Cost Source Reference

1 Harrington Plastic Catalog Price
2 Heat Exchanger Sales and Engineering Company, LLC Quote Dated July 17, 2008
3 MEGTEC Systems, Inc. Quote Dated April 20, 2008
4 BakerCorp Quote Dated July 1, 2008
5 Yardley Pump and Vacuum Quote Dated July 18, 2008
6 Verbal Qoute from Enviro Supply and Services
7 Grainger Catalog Price
8 SEC Heat Exchanger Quote Dated July 1, 2008
9 Pan America Environmental Quote Dated July 28, 2008
10 BakerCorp Quoted Dated July 23, 2008
11 McMillan-McGee November 2006 Feasibility Study for Steam Injection, Page 34
12 Cooling Tower Systems Quote Dated July 2, 2008
13 McMaster-Carr Catalog Price
14 Unit price scaled down to a 75 gpm system from $2,050,000 quote from Applied Process Technologies (June 6, 2006) for a 200 gpm system
15 Verbal Quote from J.C. Palomar Construction, Inc.

Appendix J
Table 9.6
Detailed Cost, ERH
Construction Management

Item	Consultant Labor	Quantity	Unit Cost		Cost
1	Project Manager	195	$150	/Hour	$ 29,250
2	Senior Engineer/Geologist	400	$125	/Hour	$ 50,000
3	Mid-Level Engineer/Geologist	1,062	$100	/Hour	$106,200
4	Junior/Field Engineer/Geologist	1,365	$ 75	/Hour	$102,375
5	Field Technician	1,365	$ 75	/Hour	$102,375
6	Clerical/Drafting	151	$ 50	/Hour	$ 7,528
	TOTAL CONSTRUCTION MANAGEMENT COST				$397,728

Appendix J
Table 9.7
Detailed Cost, ERH
Operations and Maintenance

Item	Consultant Labor (Operations)	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	520	$ 150	/Hour	$ 78,000	
2	Senior Engineer/Geologist	520	$ 125	/Hour	$ 65,000	
3	Mid-Level Engineer/Geologist (One Full Time Mid-Level Engineer)	2,080	$ 100	/Hour	$ 208,000	
4	Junior/Field Engineer/Geologist (One Full Time Junior Engineer)	2,080	$ 75	/Hour	$ 156,000	
5	Field Technician (Three Full Time Operators - 40 Hours per Week Each)	6,240	$ 75	/Hour	$ 468,000	
6	Clerical/Drafting	520	$ 50	/Hour	$ 26,000	
	Consultant Labor Cost for Operations				**$ 1,001,000**	

Item	Consultant Labor (Reporting, H&S, Data Mngt, and Website Maintenance)	Quantity	Unit Cost		Cost	Cost Ref.
7	Project Manager	20	$ 150	/Hour	$ 3,000	
8	Senior Engineer/Geologist	80	$ 125	/Hour	$ 10,000	
9	Mid-Level Engineer/Geologist	1,300	$ 100	/Hour	$ 130,000	
10	Junior/Field Engineer/Geologist	2,080	$ 75	/Hour	$ 156,000	
11	Field Technician	0	$ 75	/Hour	$ -	
12	Clerical/Drafting	180	$ 50	/Hour	$ 9,000	
	Consultant labor for Reporting, H&S, Data Mngt, and Website Maintenance				**$ 308,000**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
13	**Equipment Rentals**					
a	12-million BTUs/hr Low NOx Steam Generator (incl. water softening package)	0	$ 18,500	/Month	$ -	1
	Total Equipment Rentals				$ -	
14	**Consumables (Excluding Utilities)**					
a	Salt for Steam Generator Feed Water Treatment	52	$ 100	/Week	$ 5,200	
b	Virgin Coconut Shell Vapor-Phase Carbon (7,000-lbs of polishing GAC per month plus 10,000 lbs of regen system carbon changed-out after six months)	94,000	$ 1.07	/lb	$ 100,580	2
c	Vapor-Phase Carbon Change-Out Service	10	$ 1,739	/Change-Out	$ 17,390	2
d	Hydrogen Peroxide for HiPOx	166,650	$ 3.00	/Gal	$ 499,950	
e	Oxygen for HiPOx	1,165,100	$ 0.35	/100 SCF	$ 407,785	
f	3000-lb Liquid-Phase Carbon Change-Out (Includes T&D as Hazardous Waste)	48	$ 6,746	/Each	$ 323,808	3
	Total Consumables				**$ 1,354,713**	

Appendix J
Table 9.7
Detailed Cost, ERH
Operations and Maintenance

Item	Subcontractor Cost	Quantity	Unit Cost			Cost		Cost Ref.
15	**Waste Management**							
a	Vapor-Phase GAC Disposal (Listed Waste for Incineration) (incl. 10,000 lbs of regen system carbon at year end)	80,000	$	0.71	/lb	$	56,800	4
b	Vapor-Phase GAC Transportation	5	$	4,286	/Load	$	21,430	4
c	Carbon Regen System Solvent Waste Disposal (Listed Waste for Incineration)	169,500	$	0.50	/lb	$	84,750	5
d	Carbon Regen System Solvent Waste Transportation - inlcude pre heat transport	5	$	3,650	/Load	$	18,250	5
e	Filtration Generated Waste Disposal (Listed Waste for Incineration)	39,300	$	0.25	/lb	$	9,825	5
f	Filtration Generated Waste Transportation	3	$	2,800	/Load	$	8,400	5
g	Boiler Water Pre-Treatment Brine and Blowdown Off-Site Disposal (non-Haz)	43,526	$	0.14	/Gal	$	6,094	6
h	Boile Water Pre-Treatment Brine and Blowdown Transportation	5	$	950	/10,000 Gals	$	4,750	6
	Total Waste Management					**$**	**210,299**	
16	**Lab Analytical and Monitoring**							
a	Summa Can Rental	288	$	40	/Each	$	11,520	7
b	Vapor VOCs Analysis (EPA Method TO-15)	288	$	200	/Each	$	57,600	7
c	Liquid Pesticides (EPA Method 8260B)	288	$	90	/Each	$	25,920	8
d	Liquid VOC Analysis (EPA Method 8081A)	288	$	95	/Each	$	27,360	8
e	Liquid pCBSA Analysis (Modifed EPA Method 314.0)	24	$	80	/Each	$	1,920	8
f	Tedlar Bags	240	$	10	/Each	$	2,400	
g	TVA-1000B PID/FID Rental	12	$	1,200	/Month	$	14,400	9
	Total Lab Analytical and Monitoring					**$**	**141,120**	
17	**Miscellaneous**							
a	Temporary Office 24'x60' Delivery and Setup	1	$	2,939	/Each	$	2,939	10
b	Temporary Office 24'x60' Rental	12	$	1,030	/Month	$	12,356	10
c	Temporary Office 24'x60' Demobilization	1	$	1,746	/Each	$	1,746	10
d	Temporary Storage Trailer	12	$	149	/Month	$	1,784	11
e	Portable Toilet Delivery	1	$	22	/Each	$	22	12
f	Portable Toilet Rental	12	$	76	/Month	$	908	12
g	Standby Generator (800 kW)	12	$	8,775	/Month	$	105,300	13
h	Maintenance Parts	12	$	1,000	/Month	$	12,000	
i	Fed Ex and Deliveries	260	$	150	/Day	$	39,000	
j	Temporary office comm. (internet, telephone, fax)	12	$	1,000	/Month	$	12,000	
k	Operator Truck Usage (One Truck per Operator)	780	$	100	/Day/Truck	$	78,000	
	Total Miscellaneous					**$**	**266,055**	

BOE-C6-0060257

Appendix J
Table 9.7
Detailed Cost, ERH
Operations and Maintenance

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
18	Steam License for UBA	0	$ 0.50	/CY Treated	$ -	14
	Total Subcontractor Cost (O&M Year 1)				$ 1,972,186	

Item	Utilities	Quantity	Unit Cost		Cost	Cost Ref.
19	**Electricity Usage**					
a	Electrodes in UBA	11,680,994	$ 0.1045	/kWh	$ 1,220,664	15
b	HiPOx and other Treatment Equipment	10,148,151	$ 0.1045	/kWh	$ 1,060,482	15
	Total Electricity Usage				$ 2,281,146	
20	**Natural Gas for Steam Generation**	53,702	$ 1.14	/Therm	$ 61,220	16
21	**Municipal Water**					
a	Cooling Tower Makeup Water (5 GPM)	2,628,000	$ 0.0029	/Gal	$ 7,621	
b	Municipal Water for Steam Generation	518,457	$ 0.0029	/Gal	$ 1,504	
c	water for electrodes	80,416,800	$ 0.0029	/Gal	$ 233,209	
	Total Municipal Water Usage				$ 242,333	
	Total Utilities				$ 2,584,699	

	FULL SCALE CONSULTANT LABOR COST	$ 1,309,000
	FULL SCALE SUBCONTRACTOR COST w/10% MARKUP	$ 2,169,405
	UTILITIES COST (NO MARKUP)	$ 2,584,699
	TOTAL OPERATIONS AND MAINTENANCE COST	$ 6,063,104

Appendix J
Table 9.7
Detailed Cost, ERH
Operations and Maintenance

Cost Source Reference

1 Nationwide Boiler Quote Dated July 30, 2008
2 BakerCorp Quote Dated June 30, 2008. Unit price for carbon change-out services is scaled down for a 9,400-lb change-out from BakerCorp quote of $1,850 per change-out for 10,000 lbs.
3 BakerCorp Quote July 23, 2008
4 NRC Environmental Services, Inc. Quote Dated June 30, 2008
5 Clean Harbors Quote Dated October 10, 2007
6 NRC Environmental Services, Inc. Email Quote Dated July 18, 2008
7 Verbal Quote from Calscience Environmental Laboratories, Inc.
8 Verbal Quote from Test America
9 Verbal Quote from Ashtead Technology Rentals
10 Mobile Mini, Inc. Quote Dated October 11, 2007
11 Verbal Quote from Mobile Mini, Inc.
12 Verbal Quote from A-1 Coast Port-A-Toilet
13 Kohler Rental Quote Dated June 30, 2008
14 McMillan-McGee November 2006 Feasibility Study for Steam Injection, Page 33
15 Shedule A-3 LADWP Rate (Second Quarter 2008)
16 GN-10, Tier III, SoCal Gas Co. Rate (Effective May 1, 2008)

Appendix J
Table 9.8
Detailed Cost, ERH
Well Abandonment

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	70	$ 150	/Hour	$ 10,500	
2	Senior Engineer/Geologist	420	$ 125	/Hour	$ 52,500	
3	Mid-Level Engineer/Geologist	170	$ 100	/Hour	$ 17,000	
4	Junior/Field Engineer/Geologist	1,872	$ 75	/Hour	$ 140,400	
5	Field Technician	70	$ 75	/Hour	$ 5,250	
6	Clerical/Drafting	70	$ 50	/Hour	$ 3,500	
	Total Consultant Labor Cost				$ 229,150	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
1	**Mobilization/Demobilization of Drill Rig**	1	$ 2,000	/LS	**$ 2,000**	1
2	**Abandon UBA Multi-Phase Extraction Wells**					
a	Drill out well materials (upper 15 feet)	15	$ 65	/Foot	$ 975	1
b	Pressure grout well	108	$ 30	/Foot	$ 3,240	1
c	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
d	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
e	Vehicle Usage	1	$ 100	/Day	$ 100	
f	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
g	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 5,315	
	Number of Wells (1 Well Abandoned per Day)				66	
	Total for UBA Multi-Phase Extraction Well Adandonment				**350,790**	

Appendix J
Table 9.8
Detailed Cost, ERH
Well Abandonment

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
3		**Abandon Electrode Wells**					
	a	Drill out well materials (upper 15 feet)	15	$ 65	/Foot	$ 975	1
	b	Pressure Grout Electrodes	105	$ 30	/Foot	$ 3,150	1
	c	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
	d	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
	e	Vehicle Usage	1	$ 100	/Day	$ 100	
	f	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
	g	Other Direct Costs	1	$ 150	/Day	$ 150	
		Cost per Well				$ 5,225	
		Number of Wells (1 Well Abandoned per Day)				102	
		Total for Electode Well Adandonment				**532,950**	
4		**Abandon Hot Floor Multi-Phase Extraction Wells**					
	a	Pressure grout well	118.5	$ 30	/Foot	$ 3,555	1
	b	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
	c	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
	d	Vehicle Usage	1	$ 100	/Day	$ 100	
	e	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
	f	Other Direct Costs	1	$ 150	/Day	$ 150	
		Cost per Well				$ 4,655	
		Number of Wells (1 Well Abandoned per Day)				0	
		Total for Hot Floor Multi-Phase Extraction Well Abandonment				**$ -**	

Appendix J
Table 9.8
Detailed Cost, ERH
Well Abandonment

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
5	**Abandon Hot Floor Steam Injection Wells**					
a	Pressure grout well	115.5	$ 30	/Foot	$ 3,465	1
b	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
c	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
f	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 4,565	
	Number of Wells (1 Well Abandoned per Day)				0	
	Total for Hot Floor Steam Injection Well Abandonment				**$ -**	
6	**Abandon Temperature Monitoring Points**					
a	Pressure grout well	105	$ 30	/Foot	$ 3,150	1
b	Forklift and mini-hopper	1	$ 500	/Day	$ 500	1
c	Abandonment Crew per Diem	1	$ 200	/Night	$ 200	
d	Vehicle Usage	1	$ 100	/Day	$ 100	
e	Equipment Rental and Supplies	1	$ 150	/Day	$ 150	
f	Other Direct Costs	1	$ 150	/Day	$ 150	
	Cost per Well				$ 4,250	
	Number of Wells				14	
	Total for Temperature Monitoring Point Abandonment				**$ 59,500**	

Appendix J
Table 9.8
Detailed Cost, ERH
Well Abandonment

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7		**Waste Management**					
	a	Waste Tank Rental	0	$ 38	/Day	$ -	
	b	Waste Tank Rental Delivery - Mob and Demob	0	$ 900	/Each	$ -	
	c	Waste Bin Rental	360	$ 15	/Day	$ 5,400	2
	d	Waste Bin Rental Delivery - Mob and Demob	12	$ 500	/Each	$ 6,000	2
	e	Transport of Hazardous Soil Cuttings	12	$ 1,100	/Each	$ 13,200	2
	f	Disposal of Hazardous Soil Cuttings	186	$ 550	/Ton	$ 102,025	2
	g	Transport of Hazardous Mud	0	$ 500	/Each	$ -	
	h	Disposal of Hazardous Mud	0	$ 1.1	/Gal	$ -	
	i	Transport of Hazardous Water	1	$ 1,100	/Each	$ 1,100	2
	j	Disposal of Hazardous Water	1517	$ 0.8	/Gal	$ 1,214	2
	k	Waste Characterization/Profiling	2	$ 500	/Each	$ 1,000	
		Total Waste Management				$ 129,939	
		Total Subcontractor Cost w/10% Markup				**$ 1,182,696**	

TOTAL WELL ABANDONMENT COST	**$ 1,411,846**

Cost Source Reference

1 Verbal Quote from Water Development Corporation

2 Verbal Quote from NRC Environmental Services

Appendix J
Table 9.9
Detailed Cost, ERH
Demobilization

Item	Consultant Labor	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	55	$ 150	/Hour	$ 8,250	
2	Senior Engineer/Geologist	180	$ 125	/Hour	$ 22,500	
3	Mid-Level Engineer/Geologist	572	$ 100	/Hour	$ 57,200	
4	Junior/Field Engineer/Geologist	720	$ 75	/Hour	$ 54,000	
5	Field Technician	380	$ 75	/Hour	$ 28,500	
6	Clerical/Drafting	125	$ 50	/Hour	$ 6,250	
	Consultant Labor Cost				**$ 176,700**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
7	**Remove Purchased Treatment Equipment**	1	$ 317,000	/LS	**$ 317,000**	
8	**Close-Out Borings**					
a	Drilling	9	$ 12,000	/Boring	$ 108,000	1
b	Waste Disposal	9	$ 5,500	/Boring	$ 49,500	2
c	Soil Pesticides (EPA Method 8081A)	54	$ 90	/Sample	$ 4,860	3
d	Soil VOCs (EPA Method 8260B)	54	$ 95	/Sample	$ 5,130	3
e	Soil pCBSA (Modified EPA Method 314.0)	54	$ 80	/Sample	$ 4,320	3
f	Liquid Pesticides (EPA Method 8081A)	9	$ 90	/Sample	$ 810	3
g	Liquid VOCs (EPA Method 8260B)	9	$ 95	/Sample	$ 855	3
h	Liquid pCBSA (Modified EPA Method 314.0)	9	$ 80	/Sample	$ 720	3
	Total for Close-Out Borings				**$ 174,195**	
	Total Subcontractor Cost w/10% Markup				**$ 540,315**	

	TOTAL DEMOBILIZATION COST	**$ 717,015**

Cost Source Reference

1 Verbal Quote from Water Development Corporation
2 Verbal Quote from NRC Environmental Services
3 Verbal Quote from Test America

Appendix J
Table 10.0
Cost Summary
ERH
Additional Heating (70 kw-hrs/cubic yard) of Focused Treatment Area

Discount Rate 4%

Year	Activity	Detailed Cost Table	Incremental Cost (Undiscounted)	Incremental Cost (NPV)
4	Additional Heating	J-10.1 Additional Heating (70 kw-hrs/Cubic Yard)	$ 2,028,901	$ 1,734,313

Appendix J
Table 10.1
Detailed Cost, ERH
Operations and Maintenance for Additional Heating (70 kw-hrs/cubic yard)

Item	Consultant Labor (Operations)	Quantity	Unit Cost		Cost	Cost Ref.
1	Project Manager	170	$ 150	/Hour	$ 25,500	
2	Senior Engineer/Geologist	170	$ 125	/Hour	$ 21,250	
3	Mid-Level Engineer/Geologist (One Full Time Mid-Level Engineer)	640	$ 100	/Hour	$ 64,000	
4	Junior/Field Engineer/Geologist (One Full Time Junior Engineer)	640	$ 75	/Hour	$ 48,000	
5	Field Technician (Two Full Time Operators - 40 Hours per Week Each)	1,920	$ 75	/Hour	$ 144,000	
6	Clerical/Drafting	170	$ 50	/Hour	$ 8,500	
	Consultant Labor Cost for Operations				**$ 311,250**	

Item	Consultant Labor (Reporting, H&S, Data Mngt, and Website Maintenance)	Quantity	Unit Cost		Cost	Cost Ref.
7	Project Manager	10	$ 150	/Hour	$ 1,500	
8	Senior Engineer/Geologist	30	$ 125	/Hour	$ 3,750	
9	Mid-Level Engineer/Geologist	400	$ 100	/Hour	$ 40,000	
10	Junior/Field Engineer/Geologist	640	$ 75	/Hour	$ 48,000	
11	Field Technician	0	$ 75	/Hour	$ -	
12	Clerical/Drafting	67	$ 50	/Hour	$ 3,354	
	Consultant Labor for Reporting, H&S, Data Mngt, and Website Maintenance				**$ 96,604**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
13	**Equipment Rentals**					
a	12-million BTUs/hr Low Nox Steam Generator (incl. water softening package)	0	$ 18,500	/Month	$ -	1
	Total Equipment Rentals				**$ -**	
14	**Consumables (Excluding Utilities)**					
a	Salt for Steam Generator Feed Water Treatment	16	$ 100	/Week	$ 1,600	
b	Virgin Coconut Shell Vapor-Phase Carbon (5000-lbs of polishing GAC per month plus 10,000 lbs of regen system carbon changed-out just prior to beginning additional pore volume O&M)	30,000	$ 1.07	/lb	$ 32,100	2
c	Vapor-Phase Carbon Change-Out Service	4	$ 1,850	/Change-Out	$ 7,400	2
d	Hydrogen Peroxide for HiPOx	55,550	$ 3.00	/Gal	$ 166,651	
e	Oxygen for HiPOx	388,367	$ 0.35	/100 SCF	$ 135,928	
f	3000-lb Liquid-Phase Carbon Change-Out (Includes T&D as Hazardous Waste)	16	$ 6,746	/Each	$ 107,936	3
	Total Consumables				**$ 451,616**	

Appendix J
Table 10.1
Detailed Cost, ERH
Operations and Maintenance for Additional Heating (70 kw-hrs/cubic yard)

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
15	**Waste Management**					
a	Vapor-Phase GAC Disposal (Listed Waste for Incineration)					
	(incl. 10,000 lbs of regen system carbon at end of treatment)	40,000	$ 0.71	/lb	$ 28,400	4
b	Vapor-Phase GAC Transportation	3	$ 4,286	/Load	$ 12,858	4
c	Carbon Regen System Solvent Waste Disposal (Listed Waste for Incineration)	39,875	$ 0.50	/lb	$ 19,938	5
d	Carbon Regen System Solvent Waste Transportation	2	$ 3,650	/Load	$ 7,300	5
e	Filtration Generated Waste Disposal (Listed Waste for Incineration)	13,100	$ 0.25	/lb	$ 3,275	5
f	Filtration Generated Waste Transportation	1	$ 2,800	/Load	$ 2,800	5
g	Boiler Water Pre-Treatment Brine and Blowdown Off-Site Disposal (non-Haz)	14,509	$ 0.14	/Gal	$ 2,031	6
h	Boile Water Pre-Treatment Brine and Blowdown Transportation	2	$ 950	/10,000 Gals	$ 1,900	6
	Total Waste Management				**$ 78,502**	
16	**Lab Analytical and Monitoring**					
a	Summa Can Rental	140	$ 40	/Each	$ 5,600	7
b	Vapor VOCs Analysis (EPA Method TO-15)	140	$ 200	/Each	$ 28,000	7
c	Liquid Pesticides (EPA Method 8260B)	140	$ 90	/Each	$ 12,600	8
d	Liquid VOC Analysis (EPA Method 8081A)	140	$ 95	/Each	$ 13,300	8
e	Liquid pCBSA Analysis (Modifed EPA Method 314.0)	8	$ 80	/Each	$ 640	8
f	Tedlar Bags	80	$ 10	/Each	$ 800	
g	TVA-1000B PID/FID Rental	4	$ 1,200	/Month	$ 4,800	9
	Total Lab Analytical and Monitoring				**$ 65,740**	

Item	Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
17	**Miscellaneous**					
a	Temporary Office 24'x60' Delivery and Setup	0	$ 2,939	/Each	$ -	10
b	Temporary Office 24'x60' Rental	4	$ 1,030	/Month	$ 4,119	10
c	Temporary Office 24'x60' Demobilization	0	$ 1,746	/Each	$ -	10
d	Temporary Storage Trailer	4	$ 149	/Month	$ 595	11
e	Portable Toilet Delivery	0	$ 22	/Each	$ -	12
f	Portable Toilet Rental	4	$ 76	/Month	$ 303	12
g	Standby Generator (800 kW)	4	$ 8,775	/Month	$ 35,100	13
h	Maintenance Parts	4	$ 1,000	/Month	$ 4,000	
i	Fed Ex and Deliveries	80	$ 150	/Day	$ 12,000	
j	Temporary office comm. (internet, telephone, fax)	4	$ 1,000	/Month	$ 4,000	
k	Operator Truck Usage (One Truck per Operator)	160	$ 100	/Day/Truck	$ 16,000	
	Total Miscellaneous				**$ 76,116**	

BOE-C6-0060267

Appendix J
Table 10.1
Detailed Cost, ERH
Operations and Maintenance for Additional Heating (70 kw-hrs/cubic yard)

Item		Subcontractor Cost	Quantity	Unit Cost		Cost	Cost Ref.
18		**Steam License for Hot Floor**	0	$ 0.50	/CY Treated	$ -	14
		Total Subcontractor Cost				$ 671,973	

Item		Utilities	Quantity	Unit Cost		Cost	Cost Ref.
19		**Electricity Usage**					
	a	Electrodes in UBA	4,088,348	$ 0.1045	/kWh	$ 427,232	15
	b	HiPOx System and other Treatment Equipment	3,382,717	$ 0.1045	/kWh	$ 353,494	15
		Total Electricity Usage				$ 780,726	
20		**Natural Gas for Steam Generation**	17,901	$ 1.14	/Therm	$ 20,407	16
21		**Municipal Water**					
	a	Cooling Tower Makeup Water (5 GPM)	864,000	$ 0.0029	/Gal	$ 2,506	
	b	Steam Generation	172,819	$ 0.0029	/Gal	$ 501	
	c	Electrodes in UBA	26,805,600	$ 0.0029	/Gal	$ 77,736	
		Total Municipal Water Usage				$ 80,743	
		Total Utilities				$ 881,876	

CONSULTANT LABOR COST	$ 407,854
SUBCONTRACTOR COST w/10% MARKUP	$ 739,171
UTILITIES COST (NO MARKUP)	$ 881,876
TOTAL OPERATIONS AND MAINTENANCE COST FOR ADDITIONAL HEATING	$ 2,028,901

Appendix J
Table 10.1
Detailed Cost, ERH
Operations and Maintenance for Additional Heating (70 kw-hrs/cubic yard)

Cost Source Reference

1 Nationwide Boiler Quote Dated July 30, 2008
2 BakerCorp Quote Dated June 30, 2008.
3 BakerCorp Quote July 23, 2008
4 NRC Environmental Services, Inc. Quote Dated June 30, 2008
5 Clean Harbors Quote Dated October 10, 2007
6 NRC Environmental Services, Inc. Email Quote Dated July 18, 2008
7 Verbal Quote from Calscience Environmental Laboratories, Inc.
8 Verbal Quote from Test America
9 Verbal Quote from Ashtead Technology Rentals
10 Mobile Mini, Inc. Quote Dated October 11, 2007
11 Verbal Quote from Mobile Mini, Inc.
12 Verbal Quote from A-1 Coast Port-A-Toilet
13 Kohler Rental Quote Dated June 30, 2008
14 McMillan-McGee November 2006 Feasibility Study for Steam Injection, Page 33
15 Shedule A-3 LADWP Rate (Second Quarter 2008)
16 GN-10, Tier III, SoCal Gas Co. Rate (Effective May 1, 2008)

Appendix K

Update on Two Dimensional Bench Scale Testing of Steam Flushing
University of Toronto

Department of Civil Engineering
University of Toronto
35 St. George St.
Toronto, Ontario
Canada, M5S 1A4

March 17, 2009

Michael Palmer
de maximis, Inc.
1322 Scott Street, Suite 101
San Diego, California 92106

Re: Update on Two-Dimensional Bench Scale Testing of Steam Flushing

The purpose of this letter is to provide a status update of the progress to date on the two-dimensional bench scale testing of steam flushing for Montrose Corporation. The results of this testing, (analytical results, photographs, videos, temperature, and pressure data) will be provided in a final report. An updated schedule is provided at the end of this letter.

Background

The University of Toronto was contracted in 2008 by Montrose Corporation to perform two dimensional bench-scale testing using steam flushing (SF) for removal of a dense non-aqueous phase liquid (DNAPL) composed of monochlorobenzene (MCB) and DDT (as outlined in "Workplan for Two Dimensional Bench Scale Evaluation of DNAPL Mobility During Steam Flushing Montrose Superfund Site Torrance, California", September, 7, 2007 and "Addendum to the Revised Workplans for Two Dimensional Bench Scale Evaluation of DNAPL Mobility During Steam Flushing and Electrical Resistance Heating Montrose Superfund Site Torrance, California", February 21, 2008).

The two dimensional bench-scale testing was conducted due to the current level of uncertainty related to the impact of SF on DNAPL at the Montrose Site. A two dimensional bench-scale study was proposed to evaluate the importance of the various processes that could potentially occur during field-scale SF at the Site. A two dimensional study is required to investigate the significance of the various mechanisms that may influence the horizontal and vertical movement of perched DNAPL pools under SF conditions. The scale proposed, 1 meter (m) horizontal length by 60 centimeters (cm) vertical length, is sufficient to investigate these mechanisms as described in Section 6.12 of the September 2007 workplan. The use of laboratory experiments is better suited to addressing the mechanisms than a pilot study in the field due to the capacity for better control of conditions, for isolation from the surroundings, for visual observation of the experiments, and for sufficiently detailed sampling to allow quantitative analysis and preparation of mass balances. Furthermore, two dimensional studies can be conducted in a much shorter time frame than field pilot scale tests and at much lower cost.

Results of 2D Bench Scale Testing to Date

Over the past year, an existing 2D experimental cell was retrofitted for the purposes of the current study. This involved extensive reinforcement and strengthening of the cell, installation of injection and extraction wells, pressure testing, reinstallation of thermocouples and pressure transducers, and setup of a steam generator and ancillary equipment. Subsequent runs, as described in the workplan, were conducted with soils, groundwater, and DNAPL obtained from the Montrose site. The first run, the Sacrificial Run, was performed to allow determination of the physical properties of the soils as packed in the cell. This run involved packing the cell with site soils including a 25 cm thick base layer of silty sand, a 4 cm thick capillary barrier of silt (discontinuous layer), a 21 cm thick DNAPL zone of fine to medium grained sands, and an upper 10 cm thick confining layer of silty sand. Subsequently, samples were taken from each of the soil layers and sent to PTS Laboratories for determination of grain size, porosity, density, and permeability. Results indicated satisfactory reproduction of expected soil properties for each of the layers, with the exception of a slightly lower base layer permeability than expected due to a higher than anticipated silt content. The permeability of the base layer soils was increased in subsequent runs to satisfactorily reproduce source material properties. As per the workplan, no DNAPL addition or steam flushing were performed in the Sacrificial Run.

Following the Sacrificial Run, the Trial Run was performed. The cell was emptied and repacked with the same layer configuration as in the Sacrificial Run. 600 mL of DNAPL were added to the cell above the capillary barrier and allowed to redistribute for 9 days. During this time, groundwater samples were taken from below the capillary barrier to determine if there was any DNAPL movement through the capillary barrier. Analyses of these samples showed no evidence of DNAPL movement through the capillary barrier. The dissolved MCB concentration below the capillary barrier did not increase during the equilibrium period and was 0.18 mg/L on Day 9. Following groundwater sampling, steam flushing of the cell was initiated. However, plugging of the outlet well with soil fines restricted steam flow to the point where insufficient steam could be injected to heat the majority of the cell to steam temperatures. After several unsuccessful attempts over two days to relieve the plugging, the Trial Run was terminated. At this point, soil samples were taken again, as in the Sacrificial Run, for determination of physical properties. Analysis of these samples by PTS Laboratories indicated that the soil layers packed in the cell had the target properties representative of the site soils and that the partial heating achieved did not significantly alter the soil physical properties.

Following the completion of the Trial Run, Run 1 was performed on January 8, 2009, in accordance with the workplan. In this run, the cell was repacked with the same configuration of soil layers as used as in the Trial Run. However, a filter pack was placed around both the injection and extraction wells to avoid the plugging experienced in the Trial Run. As with the Trial Run, 600 mL (750 grams) of dense nonaqueous phase liquid (DNAPL) from the Montrose site (from Well UBE-4) were injected into the DNAPL zone (fine to medium grained sands) above the capillary barrier to form a DNAPL pool. Steam flushing was conducted for approximately 11 hours, with steam injected above the capillary barrier and effluents extracted from above the capillary barrier at the opposite end of the cell. Steam injection pressures were maintained between 13 and 15 psig throughout the flushing period. Soil temperatures in the DNAPL zone were between 120 and 132°C within the first 6 hours of the experiment and remained within this range for the duration of steam flushing. The entire DNAPL zone was heated during the experiment, and peak temperatures in the DNAPL zone were in the range of 125 to 132°C during steam flushing. By the end of the test, a total of 53 lb of condensate were produced, which represented approximately 3.4 times the pore volume of the DNAPL zone.

The effluent from steam flushing was collected in two Tedlar bags, with the first bag filled during the first 6 hours of steam flushing, and the second bag filled during the last 5 hours of steam flushing. During the first 6 hours of steam flushing, approximately 170 mL of DNAPL were collected in the effluent, with a monochlorobenzene (MCB) content of 68% (by weight) and a DDT content of 32% by weight based on analytical testing. DNAPL was observed in the effluent line and effluent bag shortly after commencing steam flushing, indicating that some of the DNAPL in this first effluent bag was likely hydraulically displaced from the cell ahead of the steam front. During the last 5 hours of steam flushing 85 mL of DNAPL were collected in the second effluent bag, with a composition of 94% MCB and 6% DDT by weight based on analytical testing. Consistent with the movement of the steam zone in the cell, this higher MCB content is reflective of the removal of MCB by steam distillation, with little DDT removal due to the low volatility of DDT. Based on analytical results, the average dissolved-phase concentration of MCB in the effluent condensate was 435 mg/L.

The soil cell was allowed to cool overnight, and a total of 32 discrete post-test soil samples were collected on January 9 for laboratory analysis of MCB and DDT. In post-steam flush sampling of the soil from the steam flushing cell, significant concentrations of DDT and MCB were found above, in, and below the capillary barrier based on the detailed sampling and analyses specified in the workplan. The peak concentration of MCB located 2 cm above the capillary barrier was 14,000 mg/kg indicating that significant amounts of MCB remained in the DNAPL zone after 3.4 pore volumes of steam flushing. The peak DDT concentration above the capillary barrier was 27,690 mg/kg, indicating that DDT removal from the DNAPL zone was also very low.

In sampling from the base layer below the capillary barrier, peak concentrations of MCB and DDT were 3,600 mg/kg and 9,600 mg/kg, respectively. These concentrations cannot be explained by sorbed phase and aqueous phase MCB alone and indicate that significant amounts of DNAPL moved below the capillary barrier during steam flushing. During steam flushing the capillary barrier and a portion of the base layer became desaturated. Under these conditions, the silt layer is no longer a capillary barrier to downward DNAPL movement. In addition, the steam zone peak temperatures of 125 to 132°C (maximum temperature of 132°C) are above the melting point of DDT, so DDT precipitated from MCB removal could be mobile as a liquid.

In summary, after producing 3.4 pore volumes of steam condensate, substantial MCB and DDT remained in the steam flushed zones in the cell. In addition, substantial MCB and DDT concentrations were found in soil samples taken below the capillary barrier, indicating that MCB and DDT moved below the capillary barrier during the testing, likely due to desaturation of the capillary barrier. It should also be noted that at the steam zone temperatures achieved, above the melting point of DDT, the mobility of DNAPL may be enhanced due to lowering of DNAPL viscosity and prevention of solidification of DDT as MCB is preferentially removed.

Future Plans
We are currently preparing the cell to complete Run 2, as specified in the workplan. It is expected that Run 2 will be completed by the end of April, 2009. EPA will be notified in advance of the date when Run 2 will be conducted. Following completion of Run 2, a final report will be issued and all photographs, videos, lab data and records will be documented in that report. It is anticipated that this final report will be submitted to EPA in May, 2009.

If you have any questions or comments, please contact me.

Sincerely,

Brent Sleep

Brent Sleep
Professor

Appendix L

Montrose Rebuttal Discussions

APPENDIX L

Montrose Rebuttal Discussions

Preliminary Responses to EPA Focus Questions
Pertaining to the Application of Thermal Treatment
and Hydraulic Displacement at DNAPL Sites,
CH2M Hill, November 9, 2007

HYDRAULIC DISPLACEMENT

In November 2007, under contract to EPA, CH2M Hill prepared a study entitled *Responses to EPA Focused Questions Pertaining to the Application of Thermal Treatment and Hydraulic Displacement at DNAPL Sites* (CH2M Hill, 2007). Montrose does not concur with the characterization of hydraulic displacement in that study and believes that it should not be used as a basis for evaluating RA 4 as proposed in this FS. The following preliminary remarks are provided to clarify some of the issues related to hydraulic displacement as a candidate DNAPL technology at the Site. Additional detailed Montrose comments regarding the referenced study will be provided to EPA under separate cover.

DNAPL Physical Properties: CH2M Hill evaluated the potential effectiveness of hydraulic displacement at the Montrose Site by comparing the DNAPL properties to creosote. CH2M Hill placed a great deal of emphasis on the density of creosote (approximately 1.1 g/cc at 20°C) being lower than the Montrose DNAPL (1.25 g/cc at 20°C) and questioned the ability of the Montrose DNAPL to be mobilized by hydraulic displacement due to the density difference. The Montrose DNAPL density is not so high as to preclude the use of hydraulic displacement, as proven by field pilot testing and predicted by computer modeling, and the ability of hydraulic gradients to mobilize DNAPL along horizontal layers is independent of the DNAPL density. Furthermore, a higher DNAPL density promotes gravity drainage into recovery wells, although not the primary recovery mechanism. As demonstrated by three separate field pilot tests, liquid-phase DNAPL was effectively recovered from all test wells within the mobile DNAPL footprint. Additionally, the rate of DNAPL recovery was found to increase with increasing hydraulic gradients, and hydraulic gradients under RA 4 will be higher than observed during pilot testing due to re-injection of the untreated groundwater. While creosote has a slightly lower density than the Montrose DNAPL (increasing the effectiveness of the displacing fluid, i.e., water), the Montrose DNAPL has a substantially lower viscosity than creosote (approximately 2.5 and 20 cP respectively at 20°C). The lower viscosity of the Montrose DNAPL makes it significantly more mobile than creosote under hydraulic displacement. Thermal technologies are often applied to creosote sites to lower the viscosity and increase the mobility of DNAPL-phase creosote for recovery. By comparison, the Montrose DNAPL does not require heating in order to be mobilized for extraction. CH2M Hill has placed too much emphasis on the properties of creosote, overstated the differences in DNAPL density, and did not recognize all performance advantages of hydraulic displacement applicable to the Montrose Site.

Well Spacing/Radial Capture: CH2M Hill indicated that hydraulic displacement would have a limited radial influence on mobilization of the Montrose DNAPL. However, field pilot testing and computer modeling demonstrate otherwise. Computer modeling predicts that DNAPL would be mobilized by hydraulic displacement in well spacings up to 80 feet, which is larger than either of the conceptual design scenarios considered in this FS for RA 4 (25 to 50 feet). Field pilot testing also shows that the DNAPL is effectively mobilized for recovery at all locations within the estimated mobile DNAPL footprint. Further, there is no reason to doubt that the DNAPL will be effectively mobilized by the conceptual well spacing of 50 feet proposed for RA 4. If EPA has any lingering doubts about the areal influence of hydraulic displacement, Montrose has proposed a 25-foot well spacing scenario. The higher well density should eliminate any concerns that EPA may have regarding the areal influence of hydraulic displacement. Although the higher well density increases the cost of RA 4 (from $10.8 to $12.1 MM NPV), the cost of this RA is still significantly lower than the cost for RAs 5a and 6a ($20.6 to $25.6 MM NPV).

Mass/Mobility: CH2M Hill indicated that hydraulic displacement would not remove as much DNAPL mass as thermal technologies, which is true for DNAPL-phase MCB mass. However, under all RAs, residual DNAPL mass will remain, and RA 4 will likely remove more mobile DNAPL mass than the thermal remedies. The benefit in removing DNAPL mass in the short-term is to reduce the DNAPL mobility, eliminating the potential for migration. Hydraulic displacement is a depleting technology that continually reduces DNAPL mobility until residual levels are achieved. While thermal remediation removes more MCB mass than hydraulic displacement, hydraulic displacement removes more DDT mass than thermal remediation. The thermal remediation technologies preferentially remove the volatile or MCB component of the DNAPL, leaving the DDT component behind. However, hydraulic displacement works within the existing DNAPL architecture to remove mobile DNAPL composed of both MCB and DDT. Approximately 88,700 pounds of DDT would be removed by hydraulic displacement under RA 4, assuming 80% mass removal efficiency, which would otherwise be left in-situ by the thermal remediation RAs. The additional MCB mass removal under RAs 5a and 6a does not result in the removal of more mobile DNAPL and only serves to reduce the timeframe required for long-term hydraulic containment. However, as previously discussed, an insufficient amount of DNAPL mass can be removed under RAs 5a and 6a to meaningfully reduce the hydraulic containment timeframe. Therefore, the higher MCB mass removal under RAs 5a and 6a do not benefit the remedial action in terms of containment duration. The key factor in evaluating short-term benefit is in reducing DNAPL mobility, and RA 4 would be effective in reducing DNAPL mobility. By comparison, RAs 5a and 6a increase the DNAPL mobility in the short-term.

DNAPL Distribution: CH2M Hill has suggested that a detailed understanding of DNAPL distribution is not required for thermal technologies to be effective, as compared with hydraulic displacement. That reasoning is not correct and should not be used for remedy evaluation. Under thermal remediation, DNAPL mobility is increased, so it is even more important to have a detailed understanding of DNAPL distribution than for hydraulic displacement (or at least equally important). Under thermal remediation, DNAPL mobility is increased in the short-term, liquid-phase DNAPL can be displaced, steam condensate is generated in-situ, and the MCB component of the DNAPL is volatilized. The DNAPL architecture is changed by thermal remediation, increasing the importance of fully understanding the DNAPL distribution (and movement) so that all mobilized contaminants can be effectively recovered. Otherwise, contaminant spreading or downward migration could result, thereby exacerbating the DNAPL distribution instead of reducing its mobility and mass. By comparison, hydraulic displacement works within the existing DNAPL architecture, reduces DNAPL mobility in both the short and long-term, and has a reduced risk of contaminant spreading or downward migration, as confirmed by computer modeling.

DNAPL Extent: CH2M Hill has indicated that hydraulic displacement would not reduce the DNAPL extent. Although RA 4 would not reduce the extent of DNAPL at the Site, neither would RAs 5a and 6a. All RAs would leave residual saturations of DNAPL in the UBA and outside the focused treatment area. Reduction of DNAPL extent is not an RAO for the Site, but reduction of DNAPL mobility is an RAO and is effectively met by RA 4.

Heterogeneous Lithology: CH2M Hill indicated that the heterogeneous lithology of the UBA is a disadvantage for hydraulic displacement but did not identify it as a disadvantage for steam injection. To clarify, both technologies require permeable soils, and the heterogeneous nature of the UBA will equally affect hydraulic displacement (RA 4) and steam injection (RA 5a). Neither technology has an advantage over the other relative to the lithologic conditions at the Site. Only ERH has a slight advantage in that it is not as dependent on soil permeability for heating, although the heterogeneous nature of the UBA may still be problematic for recovering MCB vapors. MCB vapors may become trapped beneath fine-grained layers and not effectively recovered, ultimately re-condensing in the subsurface. Effective recovery of MCB vapors from a 45-foot saturated, highly layered, and heterogeneous interval may be problematic, and effective vapor recovery is critical to the success of an ERH remedy. The heterogeneous UBA may additionally exhibit variations in soil resistivity, leading to desaturation of isolated areas and non-uniform heating. The resistivity of UBA soils has not been measured and is uncertain.

Mass Transfer: CH2M Hill indicated that mass transfer limitations may significantly lengthen hydraulic displacement operations and reduce long-term effectiveness. Since groundwater is re-injected untreated, other than separation and filtering solids, RA 4 is not dependent on MCB mass transfer from the DNAPL-phase to the dissolved-phase. Removing dissolved-phase MCB from the groundwater would have a marginal impact on the DNAPL mass removal and saturation reduction. The objective in re-injecting the groundwater is to enhance hydraulic gradients and increase the flow of liquid-phase DNAPL towards the extraction wells. RA 4 does not require treatment of the dissolved-phase MCB and is not reliant on mass transfer rates. Thus, identification of mass transfer limitations as a disadvantage for hydraulic displacement is unfounded.

Infrastructure/Complexity: CH2M Hill has indicated that the smaller well spacing considered for hydraulic displacement, as compared with steam injection, will increase the complexity of the remedy. Although more wells are required under RA 4 than RA 5a, the higher well density increases the certainty of the remedy, not the complexity. A thermal remediation requires significantly more infrastructure to implement than a hydraulic displacement remedy without groundwater treatment. RA 5a would require a boiler, water preconditioning system, brine disposal, temperature monitoring probes, steam injection piping and controls, and condensers/heat exchangers to cool the recovered vapors/water prior to on-Site treatment. The thermal remedies implemented under RAs 5a and 6a are more complex both in terms of capital equipment and remedial operations. Furthermore, an ERH remedy under RA 6a would require even more wells than required for a hydraulic displacement remedy under RA 4.

Duration: CH2M Hill identified that remedy duration was a disadvantage for hydraulic displacement over thermal technologies. CH2M Hill has proposed a 5-year operating duration for hydraulic displacement at the Montrose Site, while thermal remediation over a focused treatment area is expected to have an operating duration of only 1 to 1.5 years. However, both operating durations are considered relatively short compared with the hydraulic containment timeframe of more than 4,000 years. In terms of the short-term remedy duration, RAs 5a and 6a offer no meaningful advantage over RA 4.

In the 2007 study, CH2M Hill suggested that hydraulic displacement may not be effective at the Montrose Site, partially due to the density of the DNAPL. However, thermal remediation is not a presumptive remedy at DNAPL sites, and contrary to the 2007 CH2M Hill study, hydraulic displacement has been successfully implemented at chlorinated VOC DNAPL sites. Two examples sites where containment and hydraulic displacement (DNAPL recovery) were implemented, in lieu of a high cost thermal remedy, are discussed below.

Petro Processors of Louisiana, Baton Rouge, Louisiana

The Petro Processors Site in Baton Rouge, Louisiana is a 60-acre former disposal site that received an estimated 300,000 tons of waste during its operation period from 1961 until 1978, including chlorinated organic liquids. This site consists of two operable units, the Brooklawn and Scenic OUs. DNAPL composed primarily of chlorinated VOCs and some SVOCs occurs at depths up to 70 feet bgs. The remedy selected for the site consisted of five components including (1) excavation of surficial soils, (2) clay cap, (3) hydraulic containment, (4) DNAPL recovery, and (5) institutional controls. A total of 192 extraction wells and 98 collection sumps were installed at the site and operated from 1994 to 2004. During this period, an estimated 13 million pounds of DNAPL was recovered from the site. The liquid-phase DNAPL was separated from groundwater and destroyed on-site by incineration. Groundwater was treated on-site by a combination of air stripping and carbon adsorption.

Standard Chlorine of Delaware (SCD) Superfund Site, Delaware City, Delaware

The SCD Superfund Site in Delaware City, Delaware is a 40-acre chemical manufacturing facility, which began operations in 1966. The SCD facility manufactured chlorinated benzenes, including MCB, dichlorobenzenes, and trichlorobenzene. Two major releases occurred at the site during historical operations including the release of 5,000 gallons of MCB in 1981 during railcar filling and the release of 569,000 gallons of dichlorobenzene and trichlorobenzene in 1986 resulting from aboveground storage tank failure. DNAPL migrated vertically downward and accumulated above a competent clay at approximately 60 to 70 feet bgs. The selected remedy for the saturated zone at the site included three components: (1) containment using a barrier wall, (2) pump and treat for groundwater, and (3) DNAPL recovery. A bentonite slurry wall was installed up to 70 feet bgs along approximately 5,300 linear feet of the containment area (approximately 6 acres). Dissolved-phase chlorinated benzenes within the containment area occur in concentrations of 345 mg/L. The combined pump and treat and DNAPL recovery system is expected to remove 20,000 pounds during each of the first 3 years and 10,000 pounds per year thereafter. Chemical oxidation using sodium persulfate is being considered for treating shallow soils (i.e., soil mixing).

THERMAL REMEDIATION TECHNOLOGIES

Montrose also does not concur with the characterization of thermal remediation technologies in the November 2007 CH2M Hill study and does not believes that it should used as a basis for evaluating RAs as proposed in this FS. It is also noted that, based on a review of thermal case studies by both EPA and Montrose in 2007, most thermal remediation sites did not proceed to full-scale application following pilot testing. For these cases, alternate remedial actions were selected which met RAOs, protected human health and the environment, and were more cost effective than thermal remediation RAs. There are also several cases where thermal remediation was found to be less effective than expected, or ineffective in reducing contaminant mass and in-situ concentrations. In some cases, thermal remediation failure has resulted in negative impacts to human health and the environment, either through fugitive emissions or contaminant spreading and migration. Selection of a thermal remedy does not increase the certainty of remedy performance, and for the Montrose Site, the high remedy cost is not justified given the increased risks and lack of meaningful reduction in hydraulic containment duration. The following preliminary remarks are provided to clarify some of the issues related to thermal remediation as a candidate DNAPL technology at the Site. Additional detailed Montrose comments regarding the referenced study will be provided to EPA under separate cover.

Thermal Remediation of MCB-Impacted Sites: In its November 2007 thermal case studies evaluation, CH2M Hill identified the Silresim Superfund Site, Loring Quarry Site, Hill Air Force Base, and Eastland Woolen Mill as sites where MCB was thermally treated and indicated that "*performance evaluation from these project locations indicates thermal technologies would be effective for treating MCB*". The extent of thermal remediation experience in treating MCB at these sites is overstated by CH2M Hill for the following reasons:

- Loring Quarry Site: PCE was the primary contaminant at the Loring Quarry Site. MCB was not detected in pre-test groundwater samples and was only detected in trace level concentrations in fractured bedrock samples (e.g., 0.24 mg/kg with a J qualifier). No MCB was reported in vapors recovered during the steam injection demonstration project, although MCB was detected in low concentrations in some post-test groundwater samples (e.g., 0.015 mg/L). There was insufficient MCB present at this site to make any determinations regarding thermal treatment of MCB, and if anything, MCB concentrations increased slightly in groundwater following the thermal demonstration test. Furthermore, the Loring steam injection demonstration test failed because of the inability to propagate steam through factures (steam condensation occurred because the rock acted as a heat sink).

- Hill Air Force Base: A demonstration steam injection pilot test was conducted at Operable Unit 1 (OU1) in 1997. However, no MCB was reported in NAPL at OU1. 1,2-Dichlorobenzene was identified as a 0.4% component of the NAPL at this site and exhibited the lowest mass removal efficiency following thermal treatment (only 71% mass removed) of all the contaminants evaluated in the demonstration test. A second thermal remediation pilot test was conducted at OU2 at this site, but that DNAPL was primarily composed of TCE.

- Silresim Superfund Site: An ERH pilot test was conducted at this site over a very small area of only 850 square feet (one hexagonal well pattern). Although the MCB concentration in soil was reduced from 5,000 to 3.4 mg/kg at this site, this reduction occurred in the unsaturated zone between 0 and 8 feet bgs, not in the saturated zone or as part of the DNAPL remediation (10 to 40 feet bgs). Several reports referred to this remediation as a thermally-enhanced SVE. Without thermal enhancements, SVE was reported as ineffective in remediating the unsaturated zone due to low soil permeabilities, preferential flow through a gravelly subgrade, and a rising water table. A conclusion from the 2004 Five-Year Review Report (Jacobs – Tetra Tech FW Joint Venture, 2004) was that "*significant operational costs and certain technical difficulties associated with applying ERH technology to the Silresim Site also represent potential drawbacks to its application*". Furthermore, dissolved-phase MCB concentrations in groundwater upgradient of the treatment area increased between 100% and 645% following the pilot test. DNAPL at the site was reported in the EPA ROD as being primarily composed of PCE, TCE, and 1,1,1-TCA, and the most significant impacts to groundwater at the site were identified as TCE and 1,1,1-TCA.

- Eastland Woolen Mill: This site was not an in-situ thermal remediation project. The soil remediation at this site was an ex-situ soil roasting or low temperature thermal desorption project. Furthermore, the average MCB concentration in pre-remediation ex-situ soils was less than 3 mg/kg, which is not remotely comparable to the concentrations present at the Montrose Site in DNAPL-impacted soils (up to 81,000 mg/kg MCB).

Comparable Sites: CH2M Hill claims that steam injection has been successfully implemented at sites that are comparable to the Montrose Site in terms of treatment area, treatment depth, and complex heterogeneous lithology. The SCE Visalia and Savannah River Sites were identified as sites that are comparable to Montrose. However, Montrose does not concur with this assessment and believes that there are significant difference between these sites and the Montrose Site. A summary of the differences and reasons why these two sites should not be viewed as precedents for the Montrose Site are provided below:

SCE Site in Visalia, California

Contaminant: Creosote (with pentachlorophenol) and diesel were the main contaminants at SCE Visalia. Additionally, SCE reported that the creosote became an LNAPL at temperatures greater than 50°C. As a result, downward mobilization was not a significant concern for the thermal remedy.

Treatment Area: Although SCE reported steaming an area of approximately 155,000 square feet (including area outside the perimeter steam injection wells), the actual target treatment area was much smaller. Eleven (11) steam injection wells were located outside the perimeter of the treatment area. The area inside the steam injection wells was approximately 100,000 square feet, and the target treatment area was even smaller at approximately 80,000 square feet, which is half the size of the entire DNAPL-impacted area at the Montrose Site.

Lithology: The saturated zone at SCE Visalia was composed of approximately 30 feet of sand layers and 10 feet of silt aquitard. Steam was injected into the Intermediate Aquifer, which is 25 feet thick and is described as medium to coarsed-grained sand with some gravel. By comparison, the saturated UBA at the Montrose Site is a series of relatively thin interbedded sands and silts, with the silts composing at least 50% of the saturated thickness. The saturated lithology at the SCE Visalia Site is more suited to steam injection than the Montrose Site.

Steam Injection Rate: Up to 200,000 lbs/hr of steam was injected into 11 wells (15,000 to 20,000 lbs/hr per well). This is a high rate of steam injection that significantly exceeds the rate considered as part of the conceptual design for the Montrose Site. Montrose had originally proposed a total steam injection rate of 60,000 lbs/hr for the full-scale steam injection case scenario (RA 5b), but the rate was reduced to 40,000 lbs/hr following EPA comments on preliminary remedy cost estimates. The reduced rate of steam injection considered for the Montrose Site will result in a significantly lower MCB mass removal efficiency as compared with the SCE Visalia Site.

Pore Volumes: SCE reported that "approximately 8" pore volumes of steam were flushed through the Intermediate Aquifer during the steam remedy. However, for the conceptual design of RA 5a at the Montrose Site, the number of assumed pore volumes was reduced from 3 to 6 pore volumes to 2 to 3 pore volumes following EPA comments on preliminary steam remedy cost estimates. The amount of steam flushing proposed for the Montrose Site will result in significantly lower MCB mass removal efficiencies as compared with the SCE Visalia Site.

Duration/Hot Floor: At the SCE Visalia Site, steam was injected into the subsurface for a duration of 3 years, from May 1997 to June 2000. Steam was injected in two phases. During the first phase, steam was injected into the Intermediate Aquifer at 80-100 feet bgs. However, groundwater influx from the underlying Deep Aquifer resulted in excessive cooling of the thermal treatment area. As a result, a second phase was conducted with steam injected into the underlying Deep Aquifer in order to reduce the cool groundwater influx. The hot floor at the SCE Visalia Site was not implemented to reduce the potential for downward migration, but rather, it was implemented to reduce cool groundwater influx up into the thermal treatment zone. Additionally, only three injection wells were used to inject steam into the Deep Aquifer to address groundwater influx over a limited portion of the treatment area (SCE did not need to heat the entire Deep Aquifer).

Contaminant Recovery: SCE recovered between 130,000 and 150,000 gallons of liquid-phase creosote, which was more than double the volume originally estimated as being in-situ. The majority of the contaminant mass was removed as liquid-phase NAPL. Smaller percentages were recovered in the vapor-phase, dissolved-phase, or destroyed in-situ (estimated). By comparison, nearly all of the mass removal at the Montrose Site would be in the vapor-phase.

Savannah River Site (SRS) in Aiken, South Carolina

Unsaturated Zone Lithology: The unsaturated zone at the SRS Site is thick (120 feet) and interbedded with varying layers of sand and clay. Three distinct clay layers have been identified at 325, 300, and 270 feet AMSL, which correspond to 45, 70, and 100 feet bgs. SVE was implemented in the unsaturated zone in advance of the steam project, but was less effective in some layers. As a result, SRS recommended that thermal remediation be implemented to increase the permeability of the lower fine-grained unit in the unsaturated zone. At the Montrose Site, heat is not required to implement SVE in the PVS and unsaturated UBA overlying the DNAPL-impacted saturated zone.

Saturated Zone Lithology: Within the saturated zone at the SRS Site, DNAPL has accumulated in a sand aquifer that is 25-30 feet thick (M-Area Aquifer). At the Montrose Site, DNAPL occurs within a highly layered and heterogeneous aquitard (the UBA). The saturated zone at the SRS Site is significantly more amenable to steam injection than the saturated zone at the Montrose Site. The saturated zone at the SRS Site (30 feet thick) is also thinner than the saturated UBA at the Montrose Site (45 feet thick).

No Hot Floor: At the SRS Site, a low permeability clay layer (the Green Clay or 200 ft clay) underlies the M-Area Aquifer unit which effectively serves as a capillary barrier for the DNAPL. As a result, no hot floor was implemented at the SRS site. At the Montrose Site, a permeable sand aquifer unit (the BFS) underlies the DNAPL-impacted zone, and as a result, a hot floor would be required to reduce the potential for downward migration during steam injection.

Pore Volumes Flushed: SRS has reported injecting 2.5 times more steam than originally expected (based on computer model predictions) in the M-Area Aquifer. Based on EPA recommendations, only 2 to 3 pore volumes of steam flushing are considered for the Montrose Site. Had SRS ceased remedy operations at the target energy demand, it would have only removed an estimated 250,000 pounds of DNAPL, which is 60% of their current total.

Mass Removal: While SRS has removed an estimated 425,000 pounds of VOCs as a result of the steam remedy, it is unable to reliably estimate the percent of DNAPL mass removed or residual concentrations/saturations. Its original estimate of contaminant mass in place was 2 million pounds, but SRS believes that value may have been overestimated. SRS has not collected any progress soil samples and currently does not have plans to do so until the treatment zone cools down. Therefore, the technical effectiveness of the SRS thermal remediation has yet to be determined and is uncertain. Additionally, it is noted that SRS only recently "discovered" a hot spot of DNAPL in August 2008 (despite 3 years of steam injection), which increased VOC mass removal rates 30 fold for a short duration. If additional "undiscovered" DNAPL hot spots are present at the SRS Site, the technical effectiveness of the steam remedy would be reduced.

DNAPL Displacement: CH2M Hill has identified displacement of liquid-phase DNAPL (for extraction) as an advantage for steam injection over other thermal technologies which rely exclusively on contaminant volatilization. However, at the SRS Site, only 0.1% of the DNAPL mass removed to date was from liquid-phase DNAPL.

Steam Source: A source of steam was already available at the SRS Site, and there is no incremental cost to the remedy for the cost of steam (other than transmission costs to the treatment area) significantly increasing the cost effectiveness of a steam injection remedy at that Site. At the Montrose Site, steam generation would represent approximately 30% of the remedy costs.

Funding: Remediation at SRS is funded by the Department of Energy (DOE), which would not be significantly burdened by the cost of a full-scale thermal remediation (less than 1% of the annual budget for DOE environmental programs).

Steam License: DOE is a steam injection patent holder (DUS technology), and Montrose is not. DOE is not burdened with the cost of steam license fees, as Montrose would be.

Performance at Depth: CH2M Hill claims that thermal remediation has been successfully implemented at some sites to depths comparable with the Montrose Site, including the Paducah Gaseous Diffusion Site, SCE Alhambra Site, Pemaco Maywood Site, and Williams Air Force Base Site. However, these sites are not comparable to the Montrose Site and should not be used as a basis to justify a thermal remediation for the following reasons:

Pemaco Superfund Site in Maywood, California

An ERH remedy was implemented at the Pemaco Site in 2007 and 2008 to remediate dissolved-phase TCE in groundwater. Electrodes were installed from 35 to 100 feet bgs to heat a target interval of 35 to 95 feet bgs. Because groundwater occurs at 60 feet bgs, the saturated treatment thickness was 35 feet (i.e., from 60 to 95 feet bgs). The ERH contractor did not meet target temperatures in all areas of the treatment zone due to inefficiencies and limitations associated with the long electrodes, including asymmetrical electrode spacing and some slanted electrodes. After 120 days of heating, temperatures at the base of the treatment zone (95 feet bgs) were significantly lower than other temperatures in the saturated zone. Only 43% of the monitoring points reached target temperature at 95 feet bgs, and only 19% of the monitoring points reached target temperature at 100 feet bgs (the bottom depth of the electrodes). Furthermore, no DNAPL was present at the Pemaco Site, and the primary contaminant was TCE, which co-boils at temperatures 19°C lower than MCB (i.e., 73°C and 92°C respectively). There was very little contaminant mass present at the Pemaco Site and less than 100 pounds of TCE was recovered from the thermal treatment zone. EPA terminated ERH operations after 206 days because the remedy could not achieve MCLs in groundwater.

SCE Site in Alhambra, California

A thermal conductive heating remedy was implemented at the SCE Alhambra Site from 2003-2006. The average treatment depth at the site was only 20 feet bgs, with only some of the thermal remediation wells extending to 100 feet bgs. All thermal remediation was done in the unsaturated zone since groundwater occurs at more than 240 feet bgs at this site. When evaluating depth for a thermal remediation project, the important criterion is the saturated thickness. Thick saturated treatment intervals, such as present at the Montrose Site, can be problematic for thermal remedy implementation. At the SCE Alhambra Site, none of the saturated zone was heated. The thermal technology applied at this site was ISTD conductive heating (TerraTherm technology), which is not applicable to the highly chlorinated Montrose DNAPL and is not being considered as an RA in this FS. Despite the apparent success of using steam injection at the SCE Visalia Site, steam injection was not selected for the SCE Alhambra Site because: (1) steam injection would not be able to achieve the target temperature goals of 300°C to 335°C required to meet the low cleanup goals, and (2) because steam injection would pose an "*unacceptable risk of the COPCs migrating to groundwater*", resulting in contaminant plume expansion (SCE, 2002). Furthermore, the DNAPL contaminant at this site was creosote, which is substantially different from the Montrose DNAPL.

Gaseous Diffusion Plant Site in Paducah, Kentucky

An ERH pilot test was conducted at the Gaseous Diffusion Plant Site (C-400 Building) in 2003. Electrodes were installed to depths of 105 feet bgs. The saturated thickness of the pilot test was 45 feet, with the Regional Gravel Aquifer (RGA) occurring from 60 to 100 feet. A TCE DNAPL occurs at this site, has migrated downward through the unsaturated zone, and has accumulated at the base of the RGA above a low permeability confining layer (the McNairy Formation). However, as previously reported, soil temperatures of only 30°C to 70°C were achieved between 95 and 105 feet bgs at the Paducah Site because the thick treatment interval resulted in poor performance of the deep electrodes (excessive weight of the steel shot backfill). Additionally, the high hydraulic conductivity of the RGA and associated groundwater flow resulted in excessive cooling of the thermal treatment zone. Although full-scale ERH is planned for this site, it is noted that EPA recognizes the limitations of the thermal remedy by stating that "*the heating may not effectively target the deeper portions of the RGA where a significant fraction of the TCE is present*" (DOE, Office of Environmental Management, *Review Report: Building C-400 Thermal Treatment 90% Remedial Design Report and Site Investigation*, August 2007). EPA additionally indicated that steam injection was not selected for this site because it "*is complex and potentially unstable (exhibiting chaotic behavior) in the high permeability setting of the RGA*". Full-scale ERH is currently under construction, and Phase I is scheduled to commence operations in June 2009, approximately 6 years following completion of the pilot test.

Williams Air Force Base, Arizona

Steam is being injected at the former Williams Air Force Base as part of a thermal enhanced extraction (TEE) pilot project in Operable Unit (OU) 2. However, the contaminant type is an LNAPL composed of jet fuel (JP-4) and aviation gasoline, which is fundamentally different from the Montrose DNAPL. Although the LNAPL has been smeared over a thick interval due to a water table that has risen approximately 40 feet in the last ten years, a portion of the LNAPL will occur at the water table, and there is no risk of downward migration (no hot floor is required). The primary toxic constituent of the LNAPL is benzene, which is far more volatile than MCB (81 and 12 mm Hg at 1 atmosphere, respectively) and boils at a significantly lower temperature than MCB (80°C and 132°C respectively).

The pilot project is targeting a soil volume of approximately 46,000 cubic yards, which is similar to the volume considered by RA 5a but approximately 6 times smaller than the entire DNAPL-impacted area at the Montrose Site. The Air Force estimates that between 600,000 and 1.4 million gallons of LNAPL are present in the subsurface at OU2, which is approximately 8 to 18 times more contaminant volume than is believed to be present at the Montrose Site.

Steam injection activities were initiated in October 2008 and are expected to run for approximately one year. It is noted that it has taken approximately 6 years for the Air Force to execute this pilot project. The Air Force has questioned the potential effectiveness of the TEE given the lower permeability soils present in portions of the saturated zone and speculates that a lower percentage of LNAPL mass would be removed by TEE.

Groundwater occurs at approximately 160 to 170 feet bgs (as of January 2008), and steam is injected into two zones: the Upper Water-Bearing Zone (WBZ) from 170 to 195 feet bgs and the Lower WBZ from 210 to 240 feet bgs. A 15-foot thick low permeability zone separates the two WBZs. Although the Lower WBZ is composed of alternately fine and coarse-grained layers, the degree of layering is not as significant as at the Montrose Site. The Upper WBZ is also composed of alternating fine and coarse-grained layers (slightly higher percentage of fine-grained soils than the Lower WBZ), but there is a high permeability cobble zone overlying the water table that will assist with recovering LNAPL vapors and steam. The Williams Air Force Base Site is not comparable to the Montrose Site in many ways and cannot be used as a basis for comparison.

Potential for Fugitive Emissions: Thermal remediation, particularly steam injection, creates incompatibilities with certain construction materials such as plastic piping or bentonite-rich well annular seals or grouts. At the SCE Visalia Site, extraction well EW-5 suffered a catastrophic failure of the well construction materials, resulting in the dispersion of sediment up to 200 feet from the well. An estimated 30 cubic yards of sediment was dispersed over the site, with a portion of the sediment going off-site. This well failure occurred despite numerous thermal remediation experts supporting that project. At both the Silresim Superfund Site and the Cape Fear Wood Preserving Site, plastic piping materials (CPVC) suffered significant loss of mechanical integrity resulting in fugitive emissions to atmosphere. Additionally, accelerated acidic corrosion of metal piping, well casings, and fittings has occurred at conductive heating sites during implementation of TerraTherm's ISTD technology.

Even with a robust remedial design, there is an increased potential under RAs 5a and 6a for fugitive emissions to occur at surface as a result of thermal remediation. Higher pressures, higher temperatures, and multiphase flow are all factors that can lead to fugitive emissions. In spite of significant effort, agency oversight, technical expert participation, and a robust design, fugitive emissions could still occur. A relatively large number of soil borings and wells have been drilled within the DNAPL-impacted area at the Montrose Site. In spite of all efforts by Montrose and EPA, it is still possible that steam or heated vapors may escape to surface through a former soil boring or well.

Performance Monitoring through Temperature Measurements: CH2M Hill indicates that performance monitoring through subsurface temperature measurements is an advantage for thermal technologies as compared with hydraulic displacement. Although temperature monitoring does provide an additional method for monitoring performance under a thermal remedy, it should not be considered an advantage or reason for selecting a thermal remedy. Completion of the remedy will not be granted by EPA based solely on temperature measurements. EPA will still require verification of contaminant concentrations remaining in soil following completion of the remedy. Remedy completion will be based on more than just temperature measurements, and therefore addition of this monitoring parameter is not a reason for selection of RA 5a or 6a. The concentration of MCB in soil vapors recovered by a thermal remedy and a declining MCB mass removal curve are also factors that would contribute to project completion.

By way of comparison, pressure (or more specifically vacuum) is monitored in the subsurface during implementation of SVE. However, remedy completion is not granted based on achieving a certain vacuum reading in the subsurface, simply because it implies that VOCs are being evacuated. Achieving target temperature implies that MCB should be converted to vapor-phase, but it does not prove that the

MCB has been removed from the subsurface. Only soil verification samples can prove that MCB mass has been reduced.

Thermal Remedy Performance: CH2M Hill characterizes thermal remedies as being highly successful and removing significant contaminant mass, with little or no problems or risk of contaminant displacement or migration. However, this characterization is not accurate, as there are numerous thermal remediation sites that failed to meet their remedial goals, or in the case of pilot tests, proceed to full-scale application. A few examples of these thermal remediation sites (steam and ERH only) are provided below:

Naval Weapons Industrial Reserve Plant (NWIRP) Site in Bedford, Massachusetts

An ERH pilot test was conducted at the NWIRP Site in Bedford, Massachusetts in 2003. At this site, DNAPL was detected in groundwater and was composed of chlorinated VOCs including TCE and PCE (among others). Twenty-four (24) electrodes were installed on 14-foot spacing over an area of approximately 3,200 square feet. The electrodes were installed to between 50 and 60 feet bgs, and the total treatment volume was 4,148 cubic yards. However, subsurface temperatures at the base of the treatment zone (55-60 feet bgs) did not reach target temperature. The peak temperature observed at this depth in one monitoring point was 77°C, and the average temperature at 60-feet bgs was only 65°C. Less than 100 pounds of chlorinated VOCs were removed in the vapor-phase from the saturated zone as a result of this pilot test. Additionally, non-uniform heating was observed due to desaturation of the treatment area, and dissolved-phase VOC concentrations rebounded significantly following the pilot test. The dissolved-phase TCE concentration in one test area well (MW-56I) decreased from 42,000 ug/L pre-test to 3,400 ug/L post-test but rebounded to 10,000 ug/L within 10 months. Many of the problems encountered during this ERH pilot test could occur at the Montrose Site including difficulty reaching target temperature at the base of the treatment zone, non-uniform heating due to saturation, or reduced VOC mass removal.

U.S. Naval Air Station, Alameda, California

ERH was conducted at the U.S. Naval Air Station in Alameda, California to treat dissolved concentrations of VOCs in groundwater. Soil and groundwater at this site is impacted with chlorinated VOCs, primarily 1,1,1-trichloroethane, 1,1-dichloroethene, and TCE. Dissolved VOCs occurred in groundwater between approximately 7 and 20 feet bgs and were underlain by a confining bay mud formation. ERH was implemented at Plume 5-1 over an interval from 13 to

20 feet bgs. Five hexagonal arrays covering an area of approximately 15,000 square feet were remediated using a total of 35 electrodes and 59 vapor extraction wells. The ERH remedy was implemented from July through November, 2004, and the target temperature of 92°C was reached after approximately 12 weeks. After 15 weeks, a total of approximately 3,000 pounds of VOCs were removed, and ERH operations were terminated. However, desaturation of the soils was observed in some areas, and a portion of one hexagonal array (Cell No. 5) fell below target temperatures. Groundwater monitoring in this area exhibited post-remediation rebound of dissolved VOC concentrations from 82 to 1,414 ug/L. Desaturation, non-uniform heating, and contaminant rebound are potential problems that could occur at the Montrose Site, particularly given the complex lithology and relatively high co-boiling point of MCB (higher than co-boiling points of all VOC contaminants at this site).

Air Station Launch Complex 34 Site in Cape Canaveral, Florida

ERH and steam injection demonstration tests were conducted at the Cape Canaveral Air Station, Launch Complex 34, Florida in 1999/2000. At this site, a TCE DNAPL occurred within the saturated zone to depths of 45 feet bgs (water table at approximately 6 feet bgs). Thirteen (13) electrodes were positioned over an area of 3,750 square feet, and ERH was used to heat a total treatment volume of 6,250 cubic yards. An estimated 276 kW-hrs per cubic yard of electricity was applied to the subsurface, and target temperatures were reached throughout the treatment zone. However, based on detailed pre- and post-test soil verification sampling, the Navy estimated that between 80% and 93% TCE was removed or displaced from the treatment area during the test. Only 12% to 26% of the TCE mass was recovered in the vapor-phase during the pilot. The Navy indicated that the remaining TCE mass may have either been degraded or migrated outside the treatment area. Dissolved-phase TCE concentrations increased following the pilot test in two monitoring wells located west of the treatment area (IW-17S and IW-17I), and DNAPL was observed within two monitoring wells located east of the treatment area (PA-2I and PA-2D). Additionally, some TCE was lost to surface during hurricane conditions, which damaged equipment and caused the groundwater table to rise. Although target temperatures were met during this small ERH pilot test, only 12% to 26% of the TCE mass was recovered in the vapor-phase. DNAPL-phase and dissolved-phase TCE migrated outside the treatment area during the test.

Wyckoff/Eagle Harbor Superfund Site in Bainbridge Island, Washington

A steam injection pilot test was conducted at the Wyckoff/Eagle Harbor Superfund Site in 2003. This site is impacted with a creosote DNAPL (primarily PAHs and pentachlorophenols). Sixteen (16) steam injection and 7 extraction wells, screened from approximately 10 to 30 feet bgs, were installed over a 1-acre Former Process Area. The down-gradient and cross-gradient sides of the Former Process Area were enclosed with sheet piling; only the upgradient side was left open. Operating at 25% capacity, steam was injected at a peak rate of approximately 2,000 pounds per hour for a period of 6 months. Approximately 2,200 gallons of NAPL was recovered during the test, although 60,000 gallons are estimated to be present within the pilot test area. However, the pilot system never reached its design rate for steam delivery or target temperatures. Temperatures along the aquitard only reached between 40°C to 80°C. Low permeability lithologic conditions and treatment system limitations resulted in a reduced rate of steam injection at the Site. Significant equipment fouling by naphthalene crystallization occurred, and some equipment failed either due to incompatibility with the liquid-phase DNAPL or elevated temperatures (e.g., the vapor condenser seals melted). The estimated cost of the pilot steam injection system was reported to be $10 million. Full-scale steam injection costs were estimated between $60 and $80 million. This site did not proceed to full-scale steam injection, and a hydraulic displacement remedy was selected over a high cost thermal remedy. Similar problems could occur at the Montrose Site including reduced steam injection rates due to low permeability aquitard soils or equipment fouling due to DDT precipitation.

DETAILED MONTROSE REBUTTAL DISCUSSIONS

The Montrose remarks provided in this appendix are preliminary. Additional detailed rebuttal discussions regarding the referenced November 2007 CH2M Hill study, for hydraulic displacement and thermal remediation, will be provided to EPA under separate cover.

Appendix M

Compendium of DNAPL Reference Documents

Compendium of DNAPL References to be provided under a Separate Cover